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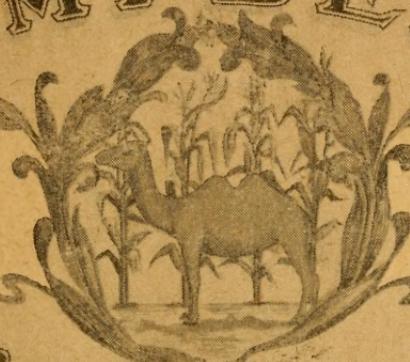
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No. 1905

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Soil Culture Manual



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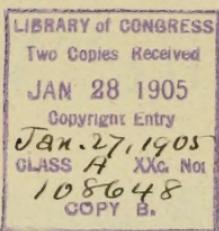
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Soil Culture Manual

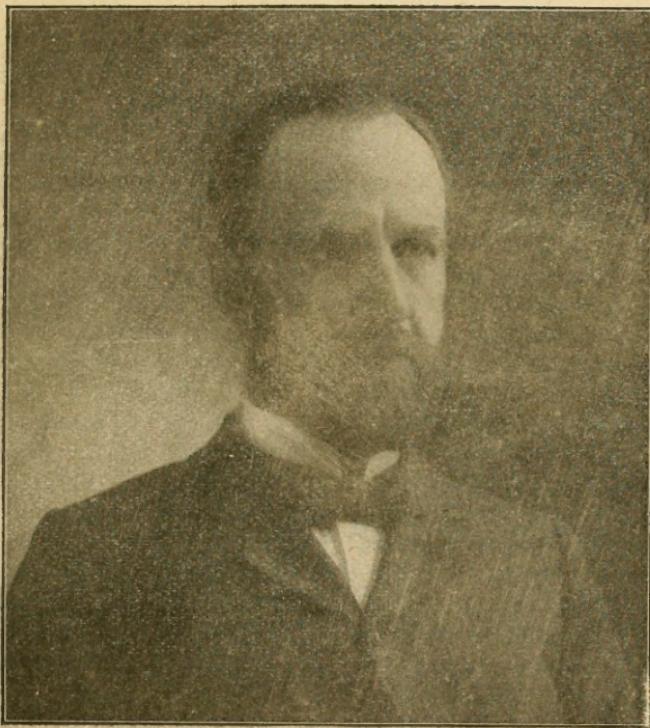


Explains how the Rain Waters are Stored and Conserved in the Soil; how Moisture Moves in the Soil by Capillary Attraction, Percolation and Evaporation; the Relation of Air to Plant Growth, and how these and the Physical Conditions of the Soil may be Regulated by Cultivation.

H. W. CAMPBELL,
AUTHOR AND PUBLISHER
LINCOLN, NEBRASKA,
U. S. A.



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Yours for better Crops and better Homes,
H. W. CAMPBELL.

West-Land Glory and Greeting.

In its new-born days—years long since gone by—
Before the people of our land
Had learned to grapple with strong hand
Soil culture problems; hearts were sore,
And poverty hung 'round the door.
But times have changed: And nevermore
From West throughout, will hear the cry
Of woe or want. Plain the reason why.
The East came West, in years gone by,
With glad refrain the west-world rings.
Each year's returns rich profit brings,
And woe, thank God, hath taken wings.
Our west-land bloometh as the rose,
Our happy youth-folk, best that grows.
Soil culture problems are solved—that's why
The west-land doth the world defy.

NELLIE HAWKS.

INTRODUCTION.

It affords me great pleasure in introducing this revised edition of my Soil Culture Manual to be able to present several new and advanced principles not mentioned in the last number. Many of these point to a still greater yield of the vast prairies of the great semi-arid belt when they are fully understood and applied.

Three years ago, when I prepared the manuscript for my first manual, I was very enthusiastic over the possible increased yields of the average farm crops by more scientific soil culture and boldly asserted that they were then not half what they might be. With three years' additional experience and observation, I do not hesitate to say, the average yield of our western prairies is not one-fourth of what it might be if our farmers would only grasp the principles involved in properly handling the soil and its relation to the plant, including the part that water, air, heat and light play separately and collectively in the growth and development of all plants; also how these elements are regulated by the physical condition of the soil and the methods by which this proper physical condition may be secured and retained through a simple system of cultivation.

I desire to present some of these general-principles in a clearer and more comprehensive manner, especially on the necessary physical condition for the proper control of available moisture and air and possibly electricity, which may play a greater part than we now comprehend.

I am sure if the young men and women of to-day would throw away that old delusive idea that the soils produce only in proportion to the proper quantities of sunshine and rainfall, regardless of the physical condition of the soil, and then grasp more fully the wonderful works of God and how by nature the necessary elements are provided for the growth and development of magnificent cereals, vegetables, fruits and flowers; and that it has been left for man to study out, combine or prepare mechanically the way for bringing together the various properties and elements in sufficient quantities and under desirable conditions for these grand results, there would be a better feeling toward the soil and its cultivation. Public sentiment with reference to farm homes and farm life would be radically changed and rural life would be universally recognized with higher, broader, and nobler aspirations.

How anyone today can observe the wonderfully improved varieties of cereals and vegetables and marvelously beautiful flowers and fruits, and realize, as he must, that they are the result of man's ingenuity in

employing nature's resources, and not be attracted to this line of work and investigation, is difficult to understand.

Scientific methods are eliminating the drudgery of the farm in this way: They are not teaching a way to avoid work but they are securing larger and surer crops for the work done. They are also awakening in the men and women on the farm the thought that they are not mere toilers, but important factors in the world's work; that it is open to them to discover methods for higher and greater possibilities in all branches of agricultural pursuits with an unlimited field of individual investigation. That agriculture is a business and the profession most important to the prosperity of nations. It supplies the material on which all other lines of development must depend to be able to carry on the diversity of interests that build up a great country or a state. Men and women on the farm must give up the idea that agriculture to-day is what it was in their grandfather's time. They have to-day a greater outlook, a broader horizon and better possibilities than in any other profession with more independence of action and happiness.

I believe the abolishment of the "bonanza" farm idea will change the unfavorable feeling regarding home life on the farm. The small farmer has given character to agriculture everywhere and at all times. He cultivates a smaller area, produces a greater diversity of crops and practices a more intensive system of cultivation. His farm is his home, which he wishes constantly to improve by the growing of trees, fruit, flowers and shrubs. He has a better conception of economy; his wife and children are happier and better contented; in short, it is on the comparatively small farms that many a bright young man and woman have found opportunities to develop a capacity for the higher and nobler duties and service of life.

Make the farm as comfortable and attractive as possible and the children will love it as their home and will feel a deeper respect for their parents, and will more fully appreciate nature in all her fruitfulness and glory and become a farmer or a farmer's wife from choice.

The "bonanza," or large scale system of farming, reverses all this; for in that case the home is not a home, but merely a place where the family stay. It is seldom beautified by trees or flowers; it is unattractive, and the very atmosphere of such a place will depress the mind of the true agriculturalist. Such a system is always barren of what is pleasing to the eye, and to the mind, and from apparent good cause the child learns to hate the farm and yearns for town or city life and its attractions.

Under the "bonanza" system, three and four acres are required to do less than one should do, and, as a rule, everything is in a state of congestion; strenuous activity abounds with, generally, unsatisfactory results. Little time is given to moral, mental, or physical culture, to the school and much less the church, or the growth of religious senti-

ment in the community, and to the broader educational work, such as the farmers' institute; and the general effect of this stunted condition is to retard the development and improvement of agriculture and the people who follow it.

It is not intended to lay down in this volume a code of imperative rules to govern the farmer in every act of soil culture, but rather by explanatory illustrations to present as clearly and plainly as possible the fundamental principles which govern the movement of moisture in the soil, the development of plant life, and the quantity and quality of the crop. After these general principles have been grasped and understood, the necessary labor in detail required to make agriculture profitable becomes clear and easy to anyone who will give these pages a careful perusal.

There cannot be laid down any rule by which to be guided in the cultivation of the soil under all conditions. Soil that is too wet, naturally, must be drained, while soil that is too dry by reason of insufficient rainfall, must have all the moisture conserved by a proper method of cultivation. In the great semi-arid area of our western country a general rule may be applied, and if followed diligently the resulting storage and conservation of the natural rainfall in the soil, together with careful preparation and such after cultivation as shall admit of the proper quantities of air, will produce in average years as good crops of cereals, and all of the vegetables that are commonly grown, as can be produced in the humid central portions of the United States.

Storage and conservation of the rain waters, and a careful observation of the necessary physical condition of the soil, is the basis of all this fruitful production. Has the reader not observed instances where a heavy snowdrift has lodged in a field, because of some obstruction in the wind's course, and where the snow was drifted the crop in the following summer was better? The usual conclusion has been that the snow drift protected the grain sown in the soil like a blanket, and the greater yield the following season was attributed to such protection; but this is an error. The reason of a greater crop on the ground so covered, was that the snow melted gradually in the spring time and percolated into the soil at a much greater depth, and was stored, as in a reservoir, and later, when the hot period and drouth of summer came, this stored moisture supplied the roots of the plants and kept the plants growing when the crop in other parts of the field not so supplied were checked and perhaps withered. By that almost inexplicable upward movement of moisture in the soil towards the surface, under a natural law which is called capillary attraction, the roots of the growing plants on the spot where the snow had drifted were supplied from the reservoir of water below, which had come down into the lower strata of the soil as the snow in the drift had melted.

We have endeavored to show that by storage and conservation of the rain waters in this way, so as to save them for plant nourishment and growth in the summer period, like results and yields may be obtained on large fields, as have been observed on small patches of ground that happened to be covered by snowdrifts. It follows, then, that the greater amount of water we can store in the soil previous to the planting of the crops, as well as during their growth, and the greater care we use in the cultivation of the surface of the ground, so as to retain and economize the moisture so conserved, the greater must be the yield at harvest time.

In connection with this fact there is another of no less importance, viz: The physical condition of the soil. The ground should be prepared as perfectly as possible to insure a prolific growth of roots. It is not uncommon that a single hour's extreme condition of the soil, as respects rapid evaporation, will reduce the crop one-half. If we can store and conserve in the soil a sufficient quantity of the natural rain waters and make them available during the growing season, and have coupled with the moisture a sufficient growth of roots to sustain and nourish the plants, a good crop is sure to be realized.

Right here let us impress upon the reader, if by chance he may be interested in irrigation, that all the general principles herein outlined having reference to the physical condition of the soil, the conservation of the soil, water and importance of air are equally valuable in irrigation.

With these considerations fully in mind, we have tried, in the following pages, to be clear in our statements and illustrations respecting all these little points and duties we owe to the cultivation of the soil, and to make plain to the reader an explanation of our past work and the results of our years of experience and experiments in the semi-arid west. A section which at a time, not far distant, we believe will be made by our system of soil culture, to yield an abundance, and will be the abode of millions of new settlers who will found homes there, blessed with peace and plenty.

May God speed the day when the masses of the people shall realize fully the truth that the vast prairies of the semi-arid belt are not simply for the grazing of a few scattered herds, but for the support of vast numbers of smaller herds and flocks and thousands of ideal farm homes interspersed with numerous flourishing towns and cities.

HOW TO USE THIS MANUAL.

It is impossible to prepare this or any other text book or manual so that any one may simply read it through and understand it fully.

It must be studied as the student studies his lesson at school; read it over and over again. The better you understand and the clearer you grasp the ideas, the more interesting will the question become, and the more successful you will be in applying the methods in detail.

Our general or common laws are based on common sense, equity and justice, yet our great lawyers have been compelled to spend years in its study, in order to be able to reason all questions fairly and truthfully. The same is true of this great question. The vital point is to be able to so understand the soil, its relation to water and plant life, as to be able to reason and comprehend fully the effect of various conditions, just what, when and how certain work should be done, and what results to reasonably expect. Knowledge is wealth, and nowhere does it more fully apply than in soil culture.

THE MODEL FARM.

No one thing has done so much toward giving the so-called Campbell system of soil culture superior standing and recognition, and made its possibilities very apparent, than the establishing of model farms. The sole object of these has been to prove to the public at large what can be accomplished in unfavorable seasons and conditions to produce good crops by substituting scientific methods of soil culture for the more common methods of cultivation. While some very marked results have been brought out the limit of possible yield in general crops, together with exceptional growth of trees, has by no means been reached.

The first of these farms to be established was the Pomeroy Model farm at Hill City, Graham county, Kansas, for which the Hon. James P. Pomeroy, of Colorado Springs, Colorado, provided the necessary funds, yet the valuable lesson and vast scope of benefits being derived from the establishing of this farm and the amount of credit due Mr. Pomeroy will never be fully appreciated. This farm was started in the spring of 1900, and for a time was under our direct supervision, but during the past two years has been under the personal care of the same man that did the work under our direction from the start.

Four consecutive winter wheat crops have been harvested from this farm, and no year has the yield been less than forty bushels per

acre. The result of this farm experiment could not be expressed in any stronger terms than found in the following letter from its owner, Mr. J. P. Pomeroy, to Mr. C. E. Wantland, general sales agent for the land department of the Union Pacific railroad, who publishes Ranch News, a Union Pacific railroad monthly:



1904 Wheat Crop, Pomeroy Farm.

Colorado Springs, Colo., May 23d, 1904.

Mr. C. E. Wantland,
Denver, Colo.,

My Dear Sir:—I wish to thank you sincerely for the copies of your paper just received. Am pleased to know that you continue to warmly recommend the Campbell process of soil culture. My experience has proven it to be all that has been claimed for it. In April of this year we had on my farm at Hill City, Graham County, Kansas, the first rain that had fallen for nearly six months, and yet at that time the moisture stored beneath our wheat fields was no less than four feet in depth, and today there are probably no finer fields of grain to be had in any part of the state than ours. It is a matter of astonishment to me that while farmers throughout that district are visiting this farm frequently and have before them such unqualified proof of the success of the "Camp-

bell System" that they are so slow to adopt it, and that when they do, are inclined to do so to such a limited extent. It is, however, a question of but a short time when they will be forced to realize that it is the only successful and sure way by which farming can be carried on and good crops produced every year, even in the driest seasons in the semi-arid belt. My success with trees of all kinds under this method has been surprising, and I feel sure that Northwestern Kansas will soon become as noted for its fruits as it is sure to be for its wonderful and diversified farm productions, and that groves of trees will be as common in our district as they are now in the Eastern portions of the State.

Very truly yours, etc.,

(Signed) J. P. Pomeroy,

To give greater force to this statement we quote the first paragraph of a second letter from Mr. Pomeroy to Mr. Wantland, dated September 10, 1904, in which he says: "I desire to thank you sincerely for recent copies of Ranch News, which you so kindly sent me, containing articles on the Campbell system of soil culture and a description of my Model farm at Hill City, Kansas, and the success which has attended its operation. We cultivate entirely under Mr. Campbell's plan. This year the wheat crop in our section was practically a failure, which was the result of the failure of our farmers to put in their crops in time and to properly cultivate. This was clearly demonstrated by the fact that on our farm we raised forty bushels of wheat per acre, and this from less than one-half bushel of seed planted."

Other farms will be opened up of the same nature during 1905, but at this writing we are not at liberty to state how many or where. Nothing has been more clearly demonstrated on these farms than the fact that summer tilling is a most valuable and strictly scientific part of soil culture, the principles of which are fully explained under that heading.

The general plan of our cultivation on these model farms will be exactly as outlined in the different chapters of this pamphlet.

The illustrations shown in cuts Nos. 14, 15 and 16, also very clearly demonstrate the value of our plan of growing and developing trees.

In our experience thus far, it is clear that in five years time one may grow up shade and ornamental trees, as well as fruit trees, to such an extent as to yield beauty, comfort and profit, which largely embody all the factors that are required to make the ideal farm home. Consider for a moment that the bleak prairie may be transformed into ideal farm homes in the short space of five years. Nothing can add more to the wealth of the country and the value of our farm lands than such improvements created generally over our western prairies. We have in mind an instance in the early settlement of eastern Nebraska which was related

to us by one of the parties concerned, that illustrates the love of the average man for trees. A man from Ohio with a reasonable amount of means had come to Nebraska to buy a farm. He was offered one with good buildings and other improvements, excepting there was no orchard or shade trees. The price asked was \$15 per acre, but he purchased the farm adjoining, on which there were no better buildings, and the land was of precisely the same character, but with an orchard of five acres and a liberal number of shade and ornamental trees around the buildings of about eight years' growth. The purchaser paid just twice the price of the other farm—investing, as you observe, as much in the fruit and



Trees, three years growth, Pomeroy Model Farm.

shade trees as he paid for the land and all the other improvements. This may have been an extreme case, but it shows quite clearly how dominant is the love in all of us for such adornments of the home as nature gives us in beautiful trees.

Outside of the pleasure and real comfort to be derived from numerous shade and ornamental trees, there is also much value in them in the protection of our fields and crops. It has long been asserted by scientists that the growing of trees on the bare prairies will increase the rainfall. If there is any reliable evidence of this to be gathered by common observation, we must admit there is truthfulness in this theory,



Raised by Campbell method.

Raised by common method.

Cut of Pomeroy Farm corn, 1901, Campbell system
vs. adjoining farm.

for in the eastern portions of Nebraska and Kansas the statements of the older settlers verify it.

In the early days, when the prairies of eastern Nebraska and Kansas were as treeless as is the extreme western portion of these states today, failure by drouth was not uncommon, while now, with almost every section of land bordered and defined by trees, and with groves and woodlands everywhere, the reverse is quite true. The effect of trees in lifting the hot south winds from the surface and carrying them over the growing crops is perceptible; especially is this noted where there is a considerable growth of trees, and a crop planted on the north side of the grove. It should therefore go without further argument that the planting of trees is important, even in the more humid portions of our country, but especially important and valuable in the semi-arid sections.

That trees can be grown in the semi-arid belt by the simple application of the "Campbell Method," there is no further question. Evidence is now too conclusive for any one to deny this assertion. Not only is this true, but with careful attention trees may be made to grow as rapidly as in any section of the East or middle West, and positive evidence of this may be seen now on the Pomeroy Model farm.

The growth of the trees in the orchard and those around the buildings is simply phenomenal. It will be worth while for anyone to visit this farm next June, though he may live hundreds of miles away. He will find there a series of surprises in the results of scientific soil culture and on his return home will cultivate his soil as it is cultivated there, being convinced, I am sure, that the principles advocated in this pamphlet are the principles to be applied to soil culture in the semi-arid belt.

THE SEMI-ARID BELT.

ITS GREAT RESOURCES AND ADVANTAGES.

That vast country known as the semi-arid belt, extending from Canada, on the north, well into Texas, and from the Rocky mountains to the Missouri river, and across that river, easterly, through the Dakotas and into western Minnesota, began to receive its first settlement in considerable numbers about twenty-five years ago.

The experiences of the people who have lived in that country of great prairies during this period have been varied in the extreme. They have had years of partial and years of total failures, and interspersed along with occasional years of good crops. Alternate hope and despair

have filled the settlers' minds. Had it not been for the cows and chickens and the small garden with the windmill as an irrigator, and the stockraising industry, much of that great section would long ago have been depopulated and abandoned as an agricultural country.

Up to 1894 very little attention had been given to the question as to how the soil of that section might be treated to insure crops, and the old method of farming was pursued, with the usually attendant disappointment.

The press drill and other tools were introduced as having the required merits for overcoming the drouth; irrigation was talked of and in some instances tried; summer fallowing was tried without any material change in crop results.

The "Rain Maker" came, and with boastful confidence in his powers attempted to perform miracles, and failed.

Trees and orchards by the thousands were planted all over that country, only to be cut down by the hot winds and the long periods of mid-summer drouth. During this time agricultural colleges were established in these states, but the conditions as respects both the climate and soil formations were all new, and it was first necessary for the professors to study and experiment to ascertain what might be done and how to do it to overcome what appeared to be insurmountable difficulties.

Not until the subject of the storage and conservation of the natural rainfall in the soil began to be comprehended did any real light or hope for the successful solution of this hard problem come to us.

The development of our investigations, pursued along this line of thought and theory, has at last brought us to the one significant conclusion, namely, that the storage and conservation of the rainfall in the soil and a careful observation of the necessary physical condition of the soil in the seed and root bed by our method of cultivation is the only means of saving that section and making it bloom and prosper and teem with people, herds and flocks.

THE DISK HARROW, ITS USE AND ABUSE.

There is no agricultural implement more important to the western farmer than the disk harrow. Its usefulness, however, from its first conception to the present time, has been more or less misunderstood. Thousands of acres of wheat have been put in by the use of the disk harrow alone that has not turned the farmer any profit, and many times a loss of not only his labor but seed. The great value of the disk har-

row lies in its adaptability to the protection of moisture, the preparation of the surface soil for the encouragement of rapid percolation of the rain water, and in thoroughly pulverizing a somewhat cloddy plowed field and getting an improved physical or mechanical condition of the soil. It has been used on thousands of acres instead of plowing, when it should have been used to precede the plow. We have quoted, under the heads of Evaporation and Cultivation, instances where the early use of the disk for the sole purpose of preventing evaporation and preparing the surface to receive and utilize further rains, has resulted in giving the farmer increased yields of corn as high as twenty bushels to the acre. Think of twenty bushels of corn per acre for only fifty cents of extra expense. In the handling of fields for summer culture there is no tool that can take the place of the disk harrow, cost of labor and value of work considered; and while it is not a tool that can be continuously used, we do not see how a man can successfully handle an orchard without it. The disk harrow may be used to prepare a field for a crop, and also in connection with the plow its work is most valuable. The complete pulverizing and thorough separating of the particles one from another in its rotating action, when proper diameter of disk is used, is perfect.

We most urgently advise the use of the disk early in the spring on all stubble ground. No time should be lost after the soil has become sufficiently thawed and dry so that it will not stick to the disk. For best results double disk the ground by lapping one-half, the object being to thoroughly pulverize and loosen the surface for a two-fold purpose. To loosen the surface and form a soil mulch to prevent the loss of moisture by evaporation as well as to break the hard crusted surface to promote a more rapid and complete percolation or soaking into the soil below of the early spring rains.

In still another season of the year we find the disk of equal value, that is immediately after the small grain or any other crop is removed. It is advised whenever possible to follow behind the harvester and not allow the soil to be exposed a single day to the sun's rays after the crop is gathered. It is very difficult to explain the value and importance of this work in sufficiently strong terms to permit the reader to grasp its full force and meaning. We will endeavor to give it in five reasons.

First: There is no time in the year when water held in the soil near the surface in sufficient quantities, will bring about so many valuable chemical changes as during the months of July and August, and these changes mean additional bushels to the next crop. But they will not take place unless the surface is loose and the soil is moist.

Second: If there is any moisture in the soil below, by preparing this fine mulch of a liberal thickness this moisture will accumulate

in the firm soil just beneath. If no more rains come your ground is in perfect condition to plow because of this moisture.

Third: If you do not wish to plow in the fall this moisture can be carried over until the next spring, when in case of a dry spring your soil, if properly handled, as I will outline later, can be planted and the seed will immediately germinate and grow while your neighbor is worrying about a dry country.

Fourth: Sometimes you may have teams and time to do some fall plowing for spring crops. If your soil is dry it is folly to plow, but if you have held the moisture in the soil it is wise to fall-plow providing you follow the plow with the sub-surface packer, firming the lower portion of the furrow slice while the soil is still moist, holding the moisture below instead of allowing the furrow to dry out, as it will, if left loose by the plow.

Fifth: In case you wish to sow fall wheat this early disking may mean ten to twenty bushels more per acre. By holding the moisture as shown above, it will be seen that any subsequent rain will percolate more quickly and deeper. If the rain be a heavy one, sufficient to dissolve and pack the loosened surface, the harrow should be thoroughly used as soon as the soil is dry enough not to stick, and by all means wait no longer. When you are ready to plow for fall wheat your soil is moist. By following the plow with the packer and the packer with the acme harrow you will have a fine firm moist seed bed and your wheat will come up, stool and grow rapidly and you need have no fears of winter killing if the seed bed is in this condition.

SIZE OF DISK.

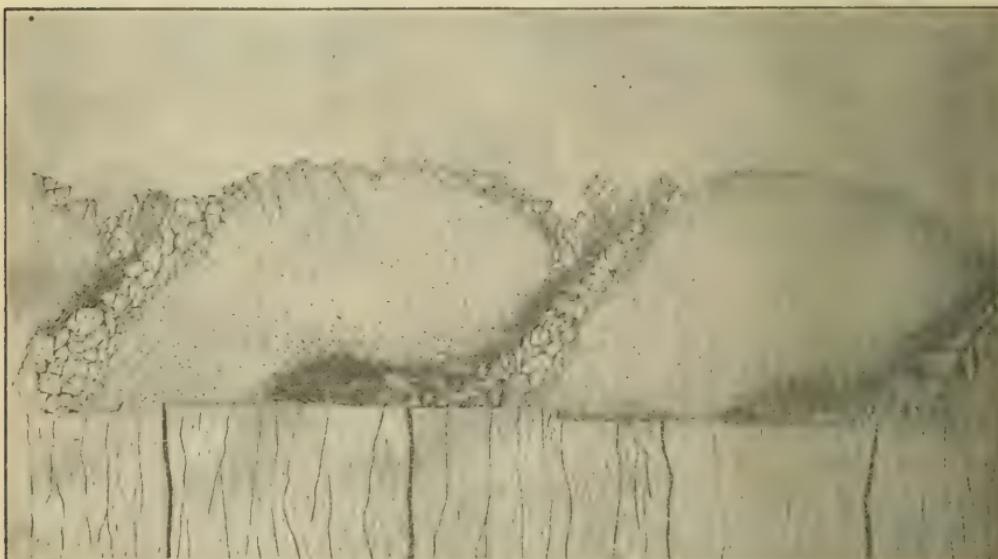
When disk harrows first came in use the common size was fourteen inches in diameter and this size we still prefer, but the demand seems to be for larger disks, the farmers conceiving the idea that they draw lighter. While this is true the pulverizing effect of the sixteen-inch is not so good as the fourteen, the eighteen-inch even less, and a twenty-inch we would not have on a farm. Just a moment's thought on this point and you will readily see the reason. The larger the disk the slower it revolves, consequently the pulverizing effect is decreased as the size of the disk is increased. I have noticed twenty-inch disks rolling along when the ground was somewhat dry, and simply slice the soil, raising it up a little and letting it fall back in large clods in exactly the same position it was before the disk passed over. The process simply made little crevices and actually increased the evaporation of moisture instead of decreasing it. A fourteen-inch disk moving along at the same rate of speed would revolve faster, therefore, pulverize and completely reverse the soil.

Don't buy a disk too large in diameter. Always double disk by

lapping one-half. This leaves the surface level if you drive so the outside disk will just fill the furrow left by the center of the disk just preceding. Keep the disk sharp. It pays. Buy as broad a disk as you have horses to draw it. Time is money. Always precede your plowing by thoroughly disking. It helps materially in obtaining a fine firm root bed.

PLOWING.

In outlining our general suggestions for securing the best possible crop results throughout this great plains country, we must of course begin with the preparation of the ground. Owing to the fact that in the settled portions the average farmer has already a sufficient area of ground under cultivation, we will start out with the preparation of ground



Cut No. 1, showing soil as plow leaves it.

that has been in crop the previous year. The first and all important work is the double disking of this ground in early spring, as explained in the preceding chapter.

It is not uncommon to see farmers double disk by first going over the ground one way and then cross disk it. This results in a series of ridges and trenches, leaving the surface very uneven. The trenches exposing the solid soil to the surface allow of much evaporation. The

proper manner of double disking is to lap half, which leaves the surface smooth and thoroughly pulverized. In the lapping of the half of the disk the last time over, the last disks revolve at right angles with the disks that precede. We cannot put too much stress upon this part of the proper preparation of the soils. Bearing in mind that the all important element for the successful growth of our crops is water, we must lose no opportunity of conserving and storing the water from the earliest part of the spring to late in the fall.

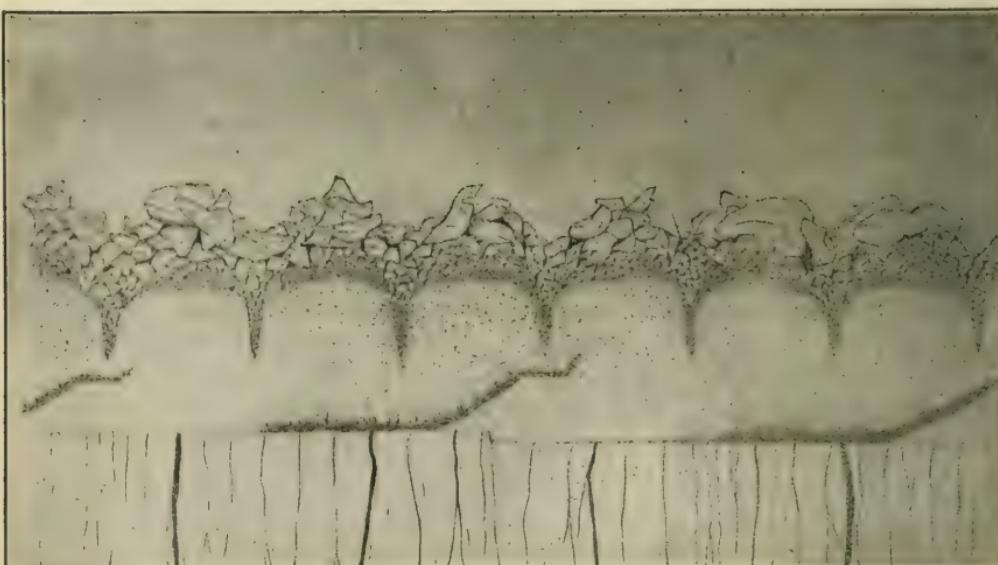
Evaporation and percolation are more fully explained in chapters to follow. After thoroughly pulverizing the surface to stop the evaporation we can do our plowing a little later, regardless of the climatic conditions which may exist, and we shall find the soil in a moist condition. It is very important that much care and attention be given to the condition of the ground at the time the plowing is done. Land should not be plowed when in bad physical condition, even though the surface soil contains more plant nourishment than the sub-surface does, for good physical conditions are very necessary for an abundance of available plant food. This cannot be obtained in the seed and root bed unless this point is given careful attention. Devote special study to what we say in chapter five with reference to the physical condition of the soil. It is one of the most important subjects in connection with its following chapter on the water-holding capacity of the soil.

In cut No. 1, we illustrate the common condition of ordinary plowed fields. Observe the appearance underneath the portion of the furrow that has been thrown over by the mouldboard on the side of the next furrow. This illustration shows a field that had not been disked before plowing.

Here is the stubble, weeds and clods that have rolled from the next furrow, while right at the point where the furrow is tipped over the soil is firm from the bottom up. The usual manner of further preparing this ground is by the use of the harrow. This has a tendency to level, and, if shallow plowed, to work the ground down fairly well at the bottom of the plowing. In deep plowing, of six or more inches, the harrow has but little effect upon these cavities underneath. This is a very serious proposition, and it is the source of many bad conditions which have a direct effect upon the final yield of the crops. First of all, it cuts off the seed or root bed from the sub-soil, preventing the movement of any moisture from the sub-soil up into the root bed. It also forms air spaces or cavities where a volume of air may exist, which aids in drying out the soil immediately adjacent. It also prevents the lateral roots and feeders from extending and permeating this portion of the soil, leaving a large per cent of our surface soil in a condition not at all beneficial to the growing crop, and were it not for the fact that these prairie soils are exceedingly fertile, they would produce far less than they do.

In cut No. 2, we show the cross-section of the same two furrows shown in cut No. 1. Here the cavities and loose condition of the soil at the bottom of the furrow have all been obliterated by the use of the sub-surface packer, which is illustrated in cut No. 3. These sharp, wedge-faced wheels have both a downward and lateral pressure against the soil in the spaces between them. The soil is moved by the packer in such a manner as to form a firm and evenly packed stratum at the lower portion of the furrow.

A word about the disk. Had this land been double disked before plowing, the stubble, weeds or manure shown in a strip at the bottom would have been scattered through the lower part of the furrow, the



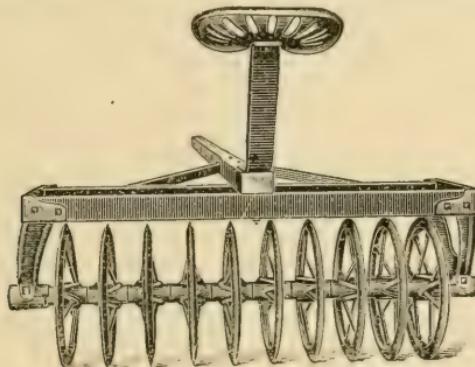
Cut No. 2, showing soil as packer leaves it.

soil made finer and the packer would have made it firmer, increasing its water-holding capacity. This would have promoted more general nitrification, facilitated greater and more uniform root growth and made it possible to have even doubled the yield of the crop, for it is not uncommon that just a little more available moisture will carry the crop to a good rain that will be ample to finish a fine crop, otherwise the crop loss might have been fifty per cent or more. This is especially true of all small grain.

After the packer has been used, by employing the ordinary smoothing harrow, or the so-called Acme harrow, the surface is pulverized and made fine and the lower part of the upper portion, which is shown as

loose and coarse in the cut, is made firm, forming a perfect seed bed. The lower part made firm by the packer, illustrated in the cut, forms the main root bed.

With this general explanation, let us return to the question of plowing. With the varied experiences of the average farmer throughout the semi-arid west there has arisen a great variety of ideas with reference to depths of plowing, and whether it is advisable to even plow more than once in two or three years. Each farmer believing he has conceived a very plausible reason why he should plow three or five inches, or why he should not plow at all. I fully appreciate the honesty and good intentions of the farmer, but the reason there is such a great variety of opinion is because he does not grasp the importance of a certain



Cut No. 3. Subsurface Packer.

physical condition of the soil, one that is favorable to holding the largest amount of moisture to the square inch; one that is favorable to the most rapid movement of moisture by capillary attraction, and one that is favorable to the most prolific growth and development of the lateral roots with their thousands of little feeders. This condition cannot be secured at its best and the largest productive results obtained without thoroughly plowing, pulverizing and packing the soil each and every year. The point gained by the plowing at a sufficient depth to stir the soil which will later contain the major part of the feeding roots is that of increasing the water holding capacity. Water is not held in the soil in cavities or spaces, but in the form of films or coverings around each diminutive soil particle, consequently the greater number of small particles of soil we have the greater the amount of water held. We can illustrate by a cube one inch square; this contains six square inches of surface. Cut this cube into eight squares, one-half inch square and we have twelve square inches of surface. Now, cutting each half-inch cube into eight one-fourth inch squares we have twenty-four square inches of surface, thereby increasing the water holding capacity four

hundred per cent. The tendency of all soil that is left for one or more years without being plowed or pulverized, is to form into larger soil grains. By the little particles adhering to each other, cemented or attached by the salts, magnesias and alkalies that are dissolved by the water as it percolates down and then moves upward, holding these properties in solution, and as the moisture passes off by evaporation, these salts and alkalies fill the little spaces, and the smaller particles form larger soil grains and decrease its capacity to hold water.

There is still another important point, and that is the thorough circulation of air in the soil. Air, like water, is an important element in the soil, and, like water, it must be finely and evenly distributed.

In further discussing the question of what is the proper physical condition of the soil when plowing is done, we would call your attention to the furrow as it is turned over by the plow when the soil is simply moist—neither very wet nor very dry. How nicely each little particle of soil seems to separate, one from the other, when, if too dry, a cloddy condition is observed; and the same is true when the soil is too wet. We should try to secure the most uniform, fine condition of our soil for the threefold purpose that it may contain more water, that moisture may move more rapidly through it, and that there may be a more prolific growth of roots. By close observation and careful attention to these important points we may secure a crop result fully one hundred per cent greater than we could obtain if these items were disregarded.

PROPER DEPTH OF PLOWING.

The proper depth of plowing must be governed very largely by the condition of the soil, the time of year that the plowing is done, the time it is to be seeded or planted and the kind of tools you have for the after work.

Take the average prairie soil, especially if level with a sand loam formation: I advise plowing fully seven inches deep if to be seeded or planted soon after. But to do this and anticipate a fair crop, the soil must be moist and not wet. The surface must be thoroughly disked before plowing and the sub-surface packer *must follow close to the plow*. The plowing done before noon should be packed before going to dinner, and that done in the afternoon packed before leaving the field at night, and then follow with the Acme harrow to get the surface in good condition before the clods get too dry.

In case of early fall plowing for spring crops and moist soil, if you have sufficient team, it will be found profitable to plow eight inches deep, following with a packer and harrow as above mentioned. If you have no sub-surface packer, beg, buy or borrow one. If you have no packer I would not advise plowing over five inches deep, and use the common harrow with teeth slightly slanting and weighted, the object

being to pulverize and firm the under portion of the furrow. These observations are very important. Much care and attention should be given to the furrow slices that they may be even in width and depth, so that when you go over the ground with your packer or harrow there may be no soil spaces left loose and porous. The average farmer must realize the great importance of thoroughly fining and firming the entire plowed portion. In the ordinary conditions as found at the bottom of furrows in plowing left without any further work until it has all dried out, shown in cut No. 1, fully one-third of the soil contributes no nourishment whatever to the growth or production of the crop. By adding a little extra pains and labor that one-third of non-productive soil may be put in condition to do its full share in making a larger and better crop. By closely following this rule you will greatly increase the quantity and quality of your crops of small grain.

BREAKING NEW PRAIRIE LANDS.

Use the regular breaking plow, cutting about two inches deep. It is best to break as shallow as it may be possible in order to turn the sod completely over and have it hold together. It should be done as soon as the grass begins to grow rapidly in the spring, turning it as flat as possible. Roll it to make it lie firmly against the sub-soil. The packer does very well if you have no roller, following with the Acme or the common harrow, going over a sufficient number of times to loosen the soil from the sod in order to fill all cracks and crevices with loose earth to form a perfect blanket. This will prevent the loss of any moisture, holding it as far as it may be possible beneath the blanket, and in case of heavy rain it will be well to harrow again. With this blanket properly provided during June and July the sod itself will not only be found to be well rotted but the top of the sub-soil to a depth of one to three inches also. In August, or as soon as the soil beneath the blanket is rotted, it should be plowed again, this time with the stirring or stubble plow cutting about two and a half inches deeper and following with the sub-surface packer, the same as outlined for ordinary stubble plowing. The harrowing should be very thorough.

If care has been taken to conserve the rain waters and the work well done, this ground may be planted to fall wheat or to spring crops the following spring, after which it should be treated the same as old ground, except to run the plow two inches deeper the next time.

There is no economy, but, on the other hand, great waste, in trying to economize or minimize the amount of labor required to thoroughly prepare the soil for the sowing or planting of grain, for the work of thorough preparation is easily and quickly done, and when once done a successful harvest is assured.

SUB-SURFACE PACKING.

The belief used to be almost universal among farmers that firming the ground, as with the roller, or making firmer the soil in any way, increased its water-holding capacity. Firming the surface of the ground does for the time increase the amount of water which may be held in the packed portion, and it is natural that this belief should have been general among farmers. Some lessons of vital importance may be learned upon this subject. The movement of the water in the soil under varying conditions of the soil and the surface should be well understood. A discussion of the subject may not seem of interest to the average farmer, yet the well established facts in regard to this subject have great weight when carefully considered in connection with the preparation of the soil for crops, and in determining their quantity and quality.

Professor F. H. King, of the University of Wisconsin, undoubtedly one of the most learned men in soil physics we have in the West, if not in the country, has recently published a book entitled "The Soil," which book should be in the hands of every farmer. In treating the question of the effect of rolling on soil moisture, he says:

"When, however, the changes in the water contents of the surface four feet of soil which follow the use of a heavy roller are studied, it is found that we have here a case of the translocation of soil moisture; a case where by destroying the many large non-capillary pores in the soil, and bringing its grains more closely together, its water-lifting power is increased and to such an extent that often within twenty-four hours after rolling, the upper one or two feet beneath the firm ground have come to contain more moisture than similar and immediately adjacent land does at the same level, while the lower two feet have become drier. Water has been lifted from the lower into the upper soil."

"In the table below will be seen the difference in the water contents of the soils which have been rolled and the immediately adjacent ones not so treated. These results are averages derived from one hundred and forty-seven sets of samples:

"Surface 36 to 54 inches, unrolled, contained 19.43 per cent of water.
Surface 36 to 54 inches, rolled, contained 18.72 per cent of water.

Difference, .71 per cent of water.

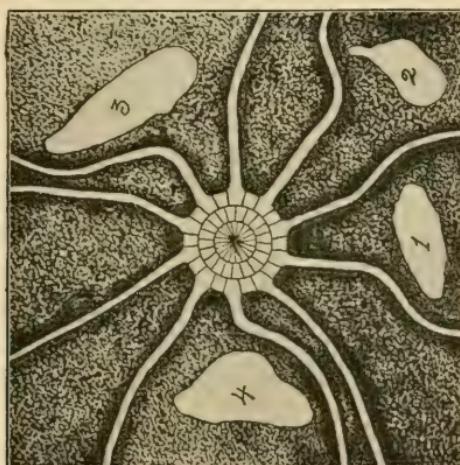
Surface 24 to 36 inches, unrolled, contained 19.85 per cent of water.
Surface 24 to 36 inches, rolled, contained 19.49 per cent of water.

Difference, .36

Surface 2 to 18 inches, rolled, contained 16.85 per cent of water.
Surface 2 to 18 inches, unrolled, contained 15.64 per cent of water.

Difference, 1.21 per cent of water.

It is here seen that when samples of soil are taken at a depth exceeding two feet, the rolled ground as a whole is drier than that not rolled, and that this difference is greater when the samples are taken at a depth of from three to four or more feet. The data presented also shows that the two to eighteen surface inches of loose ground recently firmed contains more water than that which has not been so treated. It is a matter we have carefully studied, and in all our experiment work we have observed that the statements of Professor King have been verified fully; thus affording conclusive proof of the truth of all that we have said with reference to the sub-surface packing of the soil. When the extreme surface is packed the effect is to draw the moisture to the surface where it is lost by evaporation. By the sub-packing, as shown in cut No. 2, we have that firm stratum at the point where the roots mainly grow, and with our loose mulch on the surface we prevent the loss of our moisture by evaporation.

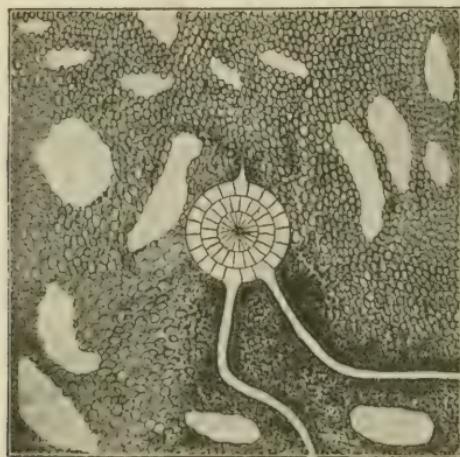


Cut No. 4, Showing development of roots in firm soil.

Results obtained by Professor King in these one hundred and forty-seven tests certainly prove very effectively the correctness of the conclusion of sub-packing by the device shown in cut No. 3. We secure a much deeper or thicker stratum of packed soil than can possibly be secured from a surface roller. This would of itself create a greater force of capillary lifting power. Then again, and don't lose sight of this fact, as the sub-packed soil lifts the moisture it is not lost by evaporation as is the moisture from the surface packed, but is held there by the loose soil mulch on the surface. This fact causes an accumulation of moisture in the packed portion which further aids in the upward movement of

the moisture from below. This translocation of water brought about by the sub-packing is of the highest importance when we reach the long dry periods so common in midsummer, and a condition we rarely fail to get sometime each and every year. We have proven by practical tests, over and over again, that by this increased movement of the moisture the plant is amply supplied, under which conditions the damage so common is not only prevented but the plant has been able to make a rapid, healthy growth right through.

When we reach a point in the extreme heated portion of the last afternoon prior to a heavy rain, where our supply of moisture is beginning to shorten, the fact that we have by this sub-surface packing been able to lift the water stored below a little faster may be the means of doubling the yield.



Cut No. 5, Showing development of roots in loose soil.

In cut No. 4, we represent the cross-section of a lateral or branch root very largely magnified. The little branches running out from the center represent the little hair roots, or feeders, which are often so small that they are scarcely perceptible to the naked eye. These little feeders are neither more nor less than little tubes, or elongated cells. You will notice in the outer tier of cells each little feeder practically forms a part of the cell. Around this root are four white spots, which represent air spaces. They are, however, extremely small, not larger than a small shot, yet, small as they are, you notice how the little feeders turn away from them. The soil where this root is located is represented to be very fine and firm. Under this condition we are able to get the greatest possible development of roots.

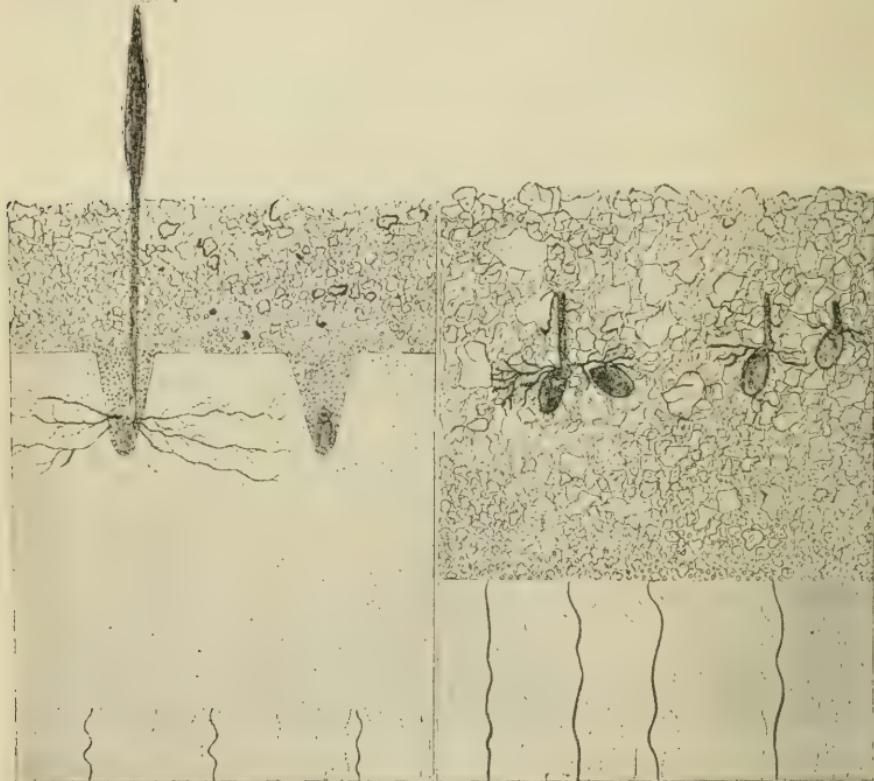
In cut No. 5, we represent a coarser or less compacted soil. Here the lateral root is only able to send out two little feeders. This condition is of much importance. We have examined roots many times and found them three, four and five inches in length, with scarcely a hair root or feeder the entire distance. Then coming, possibly, to the packed soil beneath a horse-foot track, we would find a complete net-work of little feeders running in every direction. There are two reasons for this greatly increased number of feeders in the packed soil: One is the compact condition so favorable to the development of roots; the other is the greater amount of moisture contained, which, as we have shown by a quotation from Professor King, is the result of an increased capillary attraction which has drawn moisture from below.

It is hardly possible to put too much stress upon the point of thorough pulverizing and packing the seed bed. Probably the strongest or most complete practical illustration was brought out at the Pomeroy Model farm, at Hill City, Kansas, in the growth and development of the wheat sown in the fall of 1901. This ground had been prepared with the greatest possible care, having been plowed seven inches deep, with the soil in a moist condition, kept so by the disking and harrowing of the surface. When plowed, the plow was followed closely with the sub-surface packer, and the Acme harrow following closely the sub-surface packer. By endeavoring to do all the work when the soil was in proper condition, we had secured a very favorable physical condition. At the time of seeding, October 8th, 9th, and 10th, there was a fine loose mulch on the surface two and one-half inches deep. The soil immediately beneath was very fine, firm and moist. The wheat was put in with a shoe-drill, less than one-half bushel of seed to the acre, from one-half to one inch into this fine moist soil, just beneath the mulch. Germination and development were rapid. The fourth day, as regular as the days came after seeding, the little green spears could be seen the entire length of the row. On the seventh day these leaves measured from three to four inches high. Thus, in seven days, the hard, dry seeds had become moistened, burst their shells, sent out laterally the little rootlets, and the little stalks had grown to a height of five or six inches from the seed. This is not all. On the sixteenth day of November, this wheat was taller and thicker than a field sown on the sixteenth of September, with one and one-quarter bushels of seed.

In cut No. 6 we have two conditions of soil. On the right we have the more common plan, here we find the grain of wheat in somewhat coarse and loose soil. It is in this kind of a seed bed that the wheat frequently remains all the fall without germinating; again it may sprout because of the moisture of a light shower only to wither and die from later dry windy weather or perchance may absorb just moisture enough to burst the shell and send the germ out slightly and a few feeble root-

lets, then be completely ruined by the winter freezing because of a lack of moisture in the soil about the roots to draw the frost in thawing out.

On the left we have the ideal condition, a condition that can easily be attained at a nominal expense. By the use of the sub-surface packer when the soil is in proper condition as previously explained, we get that fine, even firm condition as shown, to a depth of seven inches; then with the Aeme harrow we secure the fine loose mulch about two inches deep; with the closed heel shoe drill we secured that V-shaped opening about one inch in the firm soil into which the grain drops. As it reaches the bottom it is surrounded, except over the top, with fine firm moist soil. The fine dirt that very naturally fills this opening as the shoe moves along, puts our wheat in the ideal condition.



Cut No. 6, Germination of wheat influenced by firmness of soil.

The numerous small moist particles of soil that come in contact with the wheat conveys the moisture quickly and in ample quantities. This, coupled with the air from above brings about the very remarkable germination and development, shown at the extreme left, in the short space of five days.

Study well this illustration and note the varied conditions. The single grain at the right in the left hand section is simply to show the surrounding condition as it is deposited, compared with those in the loose soil to the right. Do not simply look at the illustration, but study the relative condition and reasonable results that may be anticipated from each.

This same quickness of germination has been noticeable at the Pomeroy farm each year since.

On the Kilpatrick Brothers' ranch in Chase county, Nebraska, where we had directed the preparing of some ground for fall wheat in 1903, the wheat was sown September 14th, the field being on a slope toward Champion, a town two and a half miles away. On the morning of the nineteenth, really but four days from seeding, the shape of the field was discernable from Champion by its green color. This statement may be emphasized from the fact that hundreds of acres of wheat were sown that fall and not another one showed green that season. Because of over seven months without rain, beginning September 10th, the Kilpatrick wheat was all that was harvested in that county, making over thirty bushels to the acre, the rest being a total failure.

We can cite many instances where the value of firming the under portion of the furrow slice has been shown to be very great. In the spring of 1899 a large amount of winter wheat in the semi-arid belt was found to have been killed. We drove over many fields that spring to investigate and study the cause as far as possible. One fact was invariably perceptible -where the soil was light and loose to a considerable depth the wheat was entirely dead. In the more compact portions or spots in the fields the condition of the wheat was found better. For instance, along the sides of the dead furrows almost all of the wheat was found to be in a perfectly healthy condition, while on the back furrows it was usually all dead. Again, at the corners of the fields where lands were plowed around, and the horses in turning had tramped and packed the plowed ground, the wheat was found to be in good condition. The horse-foot and wheel tracks invariably had a favorable effect. This is a condition and result that is corroborated by all investigators, that if there is plenty of moisture in the ground there is little or no danger of freezing or winter killing, while if the soil conditions are loose and become too dry serious results follow. The same was fully shown in the quotation from the Illinois Agricultural college bulletin, portions of which we quote under the heading of "Raising Trees." These conditions bear out all observation, both with reference to the fact that packing the soil will increase the water contents of those portions, and the further fact, as stated by the Illinois bulletin, that if there be plenty of moisture about the roots there is practically no injury from freezing.

One point which we have tried to impress upon our readers at

different times is the difficulty and danger that may arise in even a short period when the roots may be just a little short of the necessary moisture, and the importance of having a packed condition of the lower portion of the furrow slice to lessen the danger. Professor King has shown, by practical experiments, and all observation confirms his conclusions, that in soil that is packed the moisture moves upward from a depth of from one to four feet much more rapidly than in loose soil. It is therefore important to have this packing when a condition of extreme drouth is reached, as it may be the one thing that will save a crop.

Another very marked advantage of this sub-packing was found in our work at the Burlington Model farm at Holdrege, Nebraska. In 1904 a piece of ground was plowed for corn; a strip was left unpacked but all was well harrowed and the corn planted the same day. Where the packing was done the stand of corn was perfect while the strip not packed had hardly a two-thirds stand and the entire season's growth showed the advantage of packing. While the use of the sub-surface packer has been found valuable in Wisconsin and Illinois, the further west we get into the semi-arid country the greater is its importance, while in the more arid portions of the semi-arid belt its use is practically indispensable.

It must be borne in mind that Professor King experimented in packing at the extreme surface, where nearly all the moisture that had moved to this point was lost by evaporation, and that had the packing been done just below the surface the contrast would have been much greater. Professor King's experiments were on the grounds of the Wisconsin college, where soil moisture is invariably found all through the soil down to sheet water. Had they been made in our semi-arid region, the contrast would have been greater. If we get our soil moistened here to a depth of four or five feet we have exceeded by some distance the usual conditions, and this depth of soil moisture would be sufficient to carry us any ordinary season in the successful growth of crops. Had Professor King's experiments been made with a three-inch layer of loose soil mulch above the packed portion, they would have shown a much greater increase of moisture at the point of two to eighteen inches.

All these facts in connection with the movement of moisture in the soil, under different conditions of the soil, as indicated in the experiments noted and the teachings of the most eminent students of soil physics, give us the valuable lesson that the packing of the subsoil, or what may be properly termed the root-bed, aids us in these important points: increasing the water-holding capacity of the soil facilitates the movement of the water from below up to this point when it is needed, is conducive to a much greater development of root growth; and still further, and quite as important, enables us to utilize the entire soil,

having no waste ground caused by a loose or porous condition of the soil as shown in cut No. 5.

This is so important that it may be stated again plainly, so that no reader may misunderstand. The process of packing the under portion of furrow or plowed ground creates three conditions to aid in carrying the growing crop over long dry periods, namely:

1. More water in the soil.
2. A stronger capillary movement of water.
3. More prolific growth of roots.

Don't pack the surface; it increases the loss of moisture by evaporation.

Less seed is needed in packed soil than in loose soil for the same crop result.

Pack the lower portion of your plowing the same day you plow, to save the moisture.

PHYSICAL CONDITION OF THE SOIL.

By physical condition of the soil we mean the proper preparation or condition of the soil that will produce the best possible crop results; the plowing and other process of tillage to secure abundant yields. We wish to prove to you that nature has provided all necessary elements on these broad, level prairies of the semi-arid belt to grow cereals, vegetables, forage and fruits in such quantities and of such quality to make the most sanguine minds marvel.

To do this the tiller of the soil must learn what to do; when to do it; how to do it, and why he works the soil by this method which enables nature to reveal all the possibilities she stores in this workshop for an unlimited supply of crop material. We will show you that it does not require a vast amount of hard and expensive labor to get large results, but it does require effort with knowledge and judgment. Just as a valuable machine may be made powerless and useless by the wrong or slack adjustment of some bolt or nut, so in the mechanical preparation of the soil success in the highest degree depends on doing the right thing at the right time and in the right manner. You could not put a valuable machine together unless you knew something of mechanics. You cannot properly till the soil and extract from it all that nature has stored there for your use unless you understand some of the simple rules of soil physics.

Much misleading matter has been printed on the subject of soil physics and in discussing available soil fertility. Professor Milton

Whitney, chief of the bureau of soils, United States Department of Agriculture, says in Bulletin No. 22, issued by the department, "That there is no apparent relation between the chemical composition of the soil as determined by the methods of analysis used, and the yields of crops; but that the chief factor determining the yield is the physical condition of the soil under suitable climatic conditions. It is our candid opinion, based on more than twenty years' of observation and experience, that it is to the highest interest of the farmer to give little attention to the chemical properties of his soil until he has learned well and carefully its necessary physical condition in order that nature may utilize the needed chemicals of the soil and air."

The general properties or component parts of the average high level prairies of the semi-arid belt are all that could be desired. In the cultivation of these soils every precaution should be taken to prevent at any and all times during the year any loss of moisture by evaporation.

Roberts in his book on the "Fertility of the Land," says: "The percolation of rain waters not only conserves the plant food but improves the physical condition of the land. Just as soon as the soil becomes depleted of its moisture it becomes dead or dormant and life ceases."

In order to secure the best possible physical condition, the greatest care should be exercised to do the plowing, packing and cultivating while the soil is moist. When the soil is moist, as all observing farmers know, the soil grains more readily separate one from the other. The real or desirable object of plowing is not simply to turn the soil over, but in addition to turning the soil is the pulverizing. The more thoroughly this is done the better opportunity the heat, air and moisture have to exercise their full power to combine all the properties into plant foods so that they may be assimilated by the plant.

AN ILLUSTRATION.

To illustrate the most desirable mechanical or physical condition of our average prairie soils take ordinarily fine sand when dry. When these sand grains are dry there is no adhesion or resistance. They all lie close together, and yet there is a uniform size to the pores or spaces between the grains that readily admits both air and water; the water in the form of thin films or coverings to the grains and the air through the minute spaces. The heat or warmth is carried into the soil partly by the air but mainly by the contact of the particles.

SUB-PACKING NECESSARY.

In our average prairie soil of the semi-arid belt, which invariably contains more or less sand, we have a large per cent of vegetable matter in a partially decomposed state. If it is plowed when containing the

proper amount of moisture to promote a ready separation of the grains the soil is inclined to be too loose and the spaces too large. Because of this lightness of the soil in weight and the non-uniformity or irregularity in the size and the shape of the grains, it is necessary, by some process or force, to press or pack the soil more closely together as well as to more completely pulverize it.

Many methods have been tried to accomplish this. The usual one of rolling the top only packs the very part that must be kept loose. Others use the lever harrow, with teeth slanting back and weighted; also the disk harrow set straight. These help but nothing has been found so effectual as the machine designed and built expressly for the work. This is the sub-surface packer illustrated in Chapter II. After years of experiments, these wheels, with their sharp wedge-shaped face, have been reduced to the proper size, thickness and distance apart to most thoroughly pack the soil in the lower portion of the furrow slice if properly used on soils, when well plowed in the right condition to secure a most ideal mechanical condition.

FURTHER CULTIVATION.

After getting these conditions there comes the important part of the work—that of conserving the moisture and keeping the surface in condition to admit of air. Here again the greatest possible care is necessary to cultivate or work the surface when in proper condition. The farmer or tiller of the soil should keep constantly in mind that his work of fitting the soil for crops or arranging for the proper physical condition, is the all-important work of the whole year for it regulates to a very large degree his year's income.

When the farmer realizes, as he must sooner or later, that it is within his power, but dependent on his ingenuity and energy, to increase the annual products of his farm by improving the mechanism in his factory, the soil, precisely as the manufacturer increases the output of his factory by improving his machinery, he will hail with joy the day he decided to be a farmer.

Years ago, when the manufacturer found it difficult to fill his orders because of inability to manufacture a sufficient quantity, he increased the size of his factory and number of workmen. To-day, he simply improves his machinery. The farmer who increases his acres in order to increase his bushels must learn a lesson from the manufacturer. He must improve the mechanical or physical condition of the soil and thus increase its capacity of production. This can be done with less proportionate expense and more effectually than by the purchase of more acres.

WATER-HOLDING CAPACITY OF THE SOIL.

Among the more important questions involved in scientific soil culture, that are but little understood, is that of the water-holding capacity of the soil. It takes no argument to convince the average man that there are many times when, if the soil could have had just a little more available moisture, there would have been one, two or three times as great a yield. To more clearly show the vital importance, in this great semi-arid belt, of thoroughly fining and firming that portion of the soil in which the roots of the plant should grow and feed, we have prepared the accompanying illustration.



Cut No. 7, Water-holding capacity of soils.

In the glass on the right is one pound of the largest buckshot we could find; in the glass on the left is one pound of the very smallest bird shot we could obtain; in the center is an one-ounce druggist's graduate. With this graduate we measured precisely one ounce of water and turned into each glass. We then shook each glass to be sure that every shot was moistened all over. This covered each one with a thin film of water exactly as the moisture is retained around each little particle of soil. It is not possible in our illustration to get rid of the free water, or that portion between the shot, except by tipping the glass over and holding the shot back to allow all the water, which is not held in film form, to drain out into the graduate. Measuring carefully

the amount from each glass, we find to our surprise that the fine shot retains nearly thirteen times as much water as the coarse shot. Here we have a practical demonstration of how the water-holding capacity of the soil is increased by finely pulverizing and making it firm, a condition most favorable for the movement of moisture by capillary attraction and the most perfect development of roots, both of which subjects have been taken up in detail in other chapters.

The shot, before it was put into the glasses, was carefully weighed on fine druggist's scales to be sure that we had the same quantity. As you see, both glasses are filled to the same height with the coarse and fine shot and both glasses are of the same size.

The great question which bears so largely upon the quantity and quality of all crops is, that of water in sufficient available quantities at all times. Nothing has more to do with this than the mechanical or physical condition of the soil. The deeper the soil is stirred and yet made fine and firm the greater is our ability to guard against the shortage of water at some critical time. To plow deeply and leave the under-portion lumpy and loose is a very objectionable condition with which to approach a dry period, and as experience has shown, no one knows when such a time may occur. Therefore, for safety, the lower portion of the furrow must be made fine and compact.

Many thinking men, from a theoretical standpoint, insist that the soils of the prairies must be loosened up deeply to let the water down. This is not essential in the least, providing the soil is moist a foot or so below the surface and the surface is kept loose. As soon as the rain comes in contact with the moist earth below it readily percolates down through the fine soil. In fact the soil that is moist for three or four feet down will dry off on the surface much quicker than soil that is dry underneath because of more rapid percolation. The slowest soil to take the rain waters is the dry soil with a firm surface.

Again considering the water-holding capacity of the soil and recognizing a marked difference in the amount of the water held by the fine shot shown in our illustration, we more clearly grasp the value of adding well-rotted manures to the soil of the western prairies and the further importance of having it thoroughly mixed into the soil. The manure when decomposed very materially adds to the number of minute particles and further increases the water-holding capacity.

SUMMER CULTURE.

COMMONLY CALLED SUMMER FALLOW.

Summer fallowing is another feature of soil culture which has been brought from the East to the semi-arid west and applied with the same rules and ideas that prevail there and in the middle western states. Its purpose has been to give the land a rest. It has been applied to many portions of the semi-arid belt and the advantages derived have been so meager that it is losing favor. And well it may if we are to be guided in the least by six years' of experiments conducted by the South Dakota Agricultural college, as follows:

A field on which wheat was grown continuously from 1897 to 1902, inclusive, the average crop was fourteen bushels and seven pounds per acre. In order to compare this result with a rotation of summer fallowing one year and wheat the next, two plats were necessary in order to have a crop growing each year the same as on the field that was planted each continuous year. In this way no advantage of seasons was given. On these alternating plats or fields the average crop was seventeen bushels and ten pounds to the acre or only three bushels and three pounds more per acre than the field that was cropped continuously for the six years. This was a total yield of one hundred and three bushels in six years by summer fallowing half of each field each year, against one hundred and sixty-nine bushels and twenty pounds had all of both plats been planted each year.

Compare the above results reported in Bulletin No. 79, South Dakota Agricultural Experiment station, with the Pomeroy Model farm at Hill City, Kansas, where the results of wheat after our plan of summer culture in four consecutive years, 1901 to 1904, inclusive, cropped forty bushels per acre, while wheat in the same locality grown the same consecutive years, has averaged less than ten bushels. Three other fields in western Kansas and Nebraska, are authentically reported in 1904 in localities quite remote from each other, that were each summer tilled to have cropped thirty-one, thirty-six and a half and forty-one bushels, respectively, an acre, while fields in the same localities that were planted under the every year plan by the common method are reported to be from sixty to ninety per cent total failure, and the best yields did not exceed one-fourth of the above quantity.

After many years' study along these lines and watching many experiments we are confident that the results mentioned above may be continuously secured by our plan, and that even better yields will be regularly produced when the scientific principles are fully understood.

In treating the land as we would suggest we do not think the name, summer fallow, applies. Term it summer culture. Beginning the work as early in the spring as the frost is sufficiently out of the ground and the surface dry enough to permit the use of the disk harrow without the soil adhering to the disk, going over the ground twice by lapping the disk one-half. This produces a mulch which prevents evaporation; also opens and loosens the surface, so that the later rains readily and quickly percolate into the soil, harrowing the ground after each subsequent rain. If the rain is too heavy so as to dissolve and pack the surface, a second disking may be necessary, especially so if the season is advanced far enough for weeds to start freely. Don't at all hazards permit the weeds to grow or the surface to become crusted, bearing in mind our main object is to *store* the water in the soil below. Plow in June or early July, seven to eight inches deep. Do not leave the field at noon until that which has been plowed during the forenoon has been gone over with the sub-surface packer. Then at night the same, and if you use the packer follow it with the Acme harrow at night, going over the entire day's plowing. The common harrow produces very fair results or conditions, but the Acme will put this ground in better condition than two or three times over with the common harrow. In June and July weeds are quite persistent and great care should be taken not to let them get the start. In fact there is but little danger of weeds if you take care to lose no water by evaporation. All weeds are easily killed when small, but after the tap root has gone down and become firmly imbedded, the harrow, even the Acme, is not sure to destroy it. Watch the condition of your field, going over it as soon after a heavy rain as the soil will permit, using the Acme if you have one, and set it to cut about two inches deep in the solid soil. This will make you a light, loose mulch from two and a half to three inches deep. Continue this persistent care through the season; in case of extreme heat more frequent cultivation is necessary. Our rule is to watch carefully the firm soil just beneath the mulch and gauge our time of cultivation during continued dry periods by the quantity of apparent moisture, observed at the top of the firm soil beneath the mulch, or if we move the loose soil away and find there is ample moisture, the protection is all right. If the top is beginning to show dry, then it is time to cultivate again.

If desirable to put in spring crops, it is a good idea to thoroughly disk the ground as it goes into the winter. Then use the Acme early in the spring, just as soon as conditions will let you in on to the ground, unless the ground has become unusually firm by the heavy snows or rains, then it is advisable to use the disk, lapping half, following with the harrow.

If winter wheat, rye or oats are planted, care should be taken, especially in the more arid sections where fall rains of any magnitude

are less probable, to have at least two inches of fine loose soil on the surface, and if the seed bed is made fine and firm, as above outlined, not more than one-half of the usual amount of seed is necessary. Under these conditions place the seed about one inch into the fine firm soil, not over that, and by all means if you are getting a new drill, purchase the closed heel shoe drill or some drill that will leave the seed in firm soil.

While this method of summer culture seems to outline a little more work over the old method of summer fallow, yet it has been found to pay sure and marvelously large profits. The large results under this plan of cultivation come more from the kind of work done and the time it is done than from a greatly increased quantity of time and expense.

Read carefully Chapter IV and comprehend the question of care in summer culture. Fix in your mind just what you want to do. Remember it is not the object of summer culture to give the land a rest but rather the reverse. The object is to keep the land alive and actively engaged in the manufacture of plant foods and to improve the physical condition of the soil by every part of the work done, either directly or indirectly.

The great question of successful crop growing is the proper mechanical condition of the soil together with ample available moisture and a proper quantity of air in the soil during the entire growing season. No question interests the farmer more than how he may get the largest possible yield from all his crops.

It is altogether too common an idea that the quantity and quality of the crop depends upon climatic conditions. This does not apply to the semi-arid belt. The success of the farmer depends in a great measure upon the quantity and quality of the grains and vegetables he raises. Under the ordinary plan of farming the expense of preparing, planting and cultivating is just the same whether we get fifty bushels of corn or five bushels or none at all. If we proceed properly the necessary labor may be fifty per cent more, but even if it were double and we succeed in getting thirty to forty bushels of wheat in seasons when our neighbors under ordinary conditions get five or ten, does it pay? If we are able to get eighty bushels of corn when our neighbor gets thirty, does it pay?

By holding the moisture near the surface during the heated portions of the season we succeed in securing a more complete decomposition of the vegetable matter in our soil, passing it on to the stage that is known as humus, which is a most valuable element in the soil. The more humus we have the greater amount of moisture we can hold in the ground. This, coupled with the amount of moisture that we are able to store, and the improvement of the physical condition of the soil by the disking, plowing, and frequent cultivation in our summer culture, brings about three conditions. By the very fine, compact condition, our soil

will hold more water, consequently our plant is less liable to suffer from a lack of water during extreme heat. This packed condition is also, from the fact of the more minute pores in the soil, favorable to a more rapid movement of moisture by capillary attraction, and last, but not least, conducive to a more prolific growth, and a more general and uniform distribution of the roots. All three of these conditions are exceedingly important in seasons like that of 1901, when weeks go by with continuous extreme heat and no rain, and such seasons or conditions always come without warning.

It is our opinion, based on practical results and observation of conditions similar to those in western Kansas, that by the summer culture plan, storing the water the entire season, and raising crops the following year, much larger average crops may be grown than the present average in Iowa or Illinois. In fact, we do not believe we overdraw, when we say that in the more arid portions of the semi-arid belt by the summer culture plan, only cropping every other year, we can raise more wheat in ten years than can be grown in the more humid portions of the belt in ten consecutive crops by the ordinary plan. By our method we have the advantage of only seeding half the land and only harvesting half the land. The great value of work along this line lies in grasping fully the idea of storing and conserving the rain waters, and studying carefully the necessary physical condition of the soil and endeavoring to bring it to the highest degree of perfection.

If water is stored in the soils of our western prairies, nature has formed perfect and complete conditions to bring this moisture back by capillary attraction to feed the plants during the dry periods and there can be no possible loss by drouth. In fact, when the conditions are understood and the necessary labor properly applied, records of phenomenal yields will be numerous as far west as the foot hills of the Rockies.

The following from E. F. Stevens, of the Crete nursery, shows the value of summer culture, even in the more humid portions of the semi-arid belt. He says: "Regarding the possibility of carrying moisture conserved one year over into the next season for use for the next crop, we remember that one year we grew a crop of seedlings on elevated table lands on a part of the divide between the Blue and Salt creek, just south-east of Crete. Seedlings for their best growth require very frequent cultivation. They are cultivated weekly and oft times twice a week, to secure the largest possible growth and the best grade obtainable in a few months. This superior culture conserved moisture but we did not so understand it then. As a rule a crop of seedlings does not take up all the annual rainfall, so quite a portion of this conserved moisture was carried over until the next season. The following year on this plat of ground previously devoted to seedlings, as above stated, we secured 105 bushels and forty pounds of corn per acre."

This marvelous yield referred to by Mr. Stevens is the direct result of the careful cultivation which resulted in storing a large surplus of moisture, and it is fair and reasonable to conclude that equally as good, if not better, results may be gained in any portion of Nebraska, Kansas, or western Iowa, and Missouri, by following our plan of summer culture.

To get the best results the farmer's mind must be clear on three important points: That the ground must be in proper condition when all his work is done on the soil; that he must have a good, fine and firm root or seed bed and an abundance of moisture stored below.

In closing this chapter it may be very interesting as well as very conclusive evidence of the correctness of our claims, to give a few of the very marked conditions that surrounded some of the fields of wheat in the spring of 1904 on the Pomeroy Model farm at Hill City, Kansas, during the long continued early drouth. When most fields under ordinary methods of cultivation were showing no growth and no apparent moisture, the Model farm wheat was making rapid growth carrying a dark green color, while five feet of moisture was found below. Another field near Grainfield, Kansas, was in the same condition; another near Champion, Nebraska, and another near Trenton, Nebraska. The latter yielded forty-one bushels per acre while ninety per cent of the entire wheat crop in that locality was a total failure. Every wheat field in western Nebraska and Kansas might have yielded as much as the Trenton field had the land been treated by our method and the heavy rains of 1903 been stored in the soil and reserved for the long dry spring of 1904. Do not confound summer culture with summer fallowing. They are different.

Summer culture previous to seeding to alfalfa will insure a positive and even catch and a fair crop the first season.

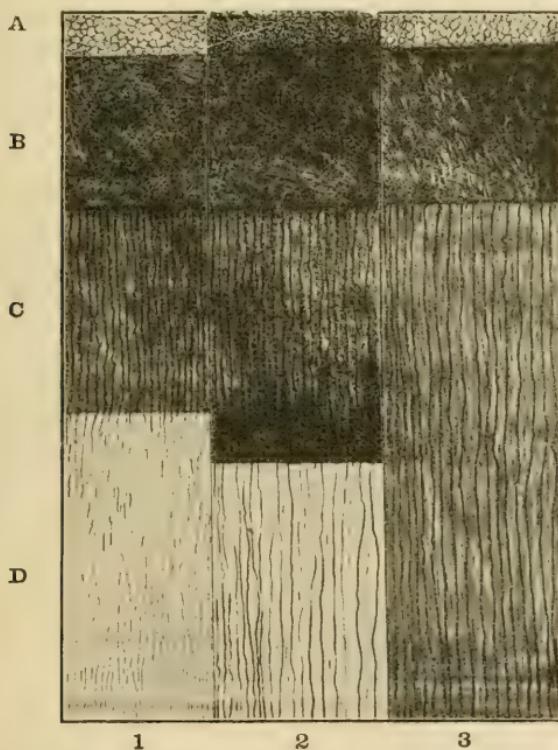
Summer culture for the storing of the rain waters in the soil, although comparatively new as outlined, is a most important adjunct in farming in the West.

Begin your summer culture as early in the spring as the conditions will let you on the ground with your disk harrow. Don't let the weeds grow, thinking they are valuable as a fertilizer to turn under. The moisture they take from the ground is worth far more to you in growing the next crop.

PERCOLATION.

OR GETTING WATER DOWN INTO THE SOIL.

The problem of getting the water down into the soil is one of equal importance to that of conserving the moisture, which is now quite commonly understood, and accomplished by the use of the soil mulch or surface cultivation. In cut No. 8 we have attempted to illustrate the percolation of water, or the getting of water down into the soil. We have divided this cut into three sections, numbering them 1, 2, and 3, from



Cut No. 8, Percolation of water, how influenced.

left to right, then divided these sections into lateral strata A, B, C, and D. In section No. 1, A represents the soil mulch, a stratum of light, loose, and dry soil; B represents a stratum of thoroughly pulverized and firm soil, meaning the portion that is cut by the plow; C represents about eight inches of the sub-soil into which water has percolated; and D represents the portion of sub-soil still below that is yet dry. In

section 2, we find the mulch has been compacted by a heavy fall of rain. This mulch in its loose condition readily takes in the water, and as soon as the water reaches the moist soil found in strata B and C, it immediately percolates down below, and is shown by the darker portion of soil in the upper part of stratum D. Here the water has come in contact with dry soil, which resists percolation. Slowly and steadily by gravity the water finds its way down the columns of soil, which by the way, throughout the entire semi-arid belt are almost invariably found in a perpendicular position. In section 3, we have again reproduced our soil mulch by cultivation to stop the evaporation or loss of our water from the surface, and we find the moisture below has percolated on down until the water is all distributed, each little particle taking on its film of water to a given thickness which it seems to steadily hold onto while the balance of the free water finds its way on down until it is all distributed. The next rain will result the same as is shown in section 2, only we have six, eight, or twelve inches more moist soil for it to pass through before reaching the dry soil.

An illustration will make this more clear. In setting out our cabbage or tomato plants in the spring of the year when the surface is dry and fine we usually water them. In our first application of water to this dry surface we notice the water does not seem to percolate, but for a little time remains dormant on the surface. After a little it finds its way down through the dry particles by force of gravity, leaving each particle it passes covered with a thin film of water. Then we apply a second application of water while the surface is still moist and we notice the water immediately disappears. The reason of non-percolation of the first application is because of the resistance of the dry particles to moisture, or repulsion for water. The quick movement of the second application of water into the ground is the result of the attraction of water for water.

The following will illustrate this natural law: take a piece of glass, or a smooth earthen plate and oil it slightly, then put drops of water, a half dozen or more on the glass, take a narrow piece of ordinary newspaper, about one-half inch wide, let it extend from the thumb and finger about two inches, slowly move it down so the end of the paper will come in contact with a single drop of water. If you notice closely you will see a remarkable resistance of the paper against the water. Very soon the little pores begin to absorb the water, and the end of the paper becomes moist. Now slowly raise the paper and notice how persistently the paper hangs to the water. When it lets go there is a quick upward movement, thus showing the power of attraction of water for water. Now steadily move the fingers down slowly, watching the paper and you will notice when it gets close to the water there is a sudden movement down, even while there is a little space between the moisture on the paper

and the water on the glass. The power of attraction is made very perceptible by the quick connection of the two moist particles. Now draw the paper across the glass from one drop to the other, you will notice the water all hangs together. You have a string or train of water two or three inches long trailing on behind your paper.

This illustrates how easy it is to get moisture into the soil by keeping the surface constantly loose and open, so that as the rain falls it soon works its way through the larger pores until it reaches the moist particles in the firm soil when it immediately percolates on down below. Here again nature has done a great deal for the semi-arid belt. The peculiar formation and size of the usual particle of soil is very favorable for percolation; also for its return upward by capillary attraction to feed the plant during our long dry seasons. The movement of this moisture upwards cannot be better illustrated than by the movement of the oil up the lamp wick. No matter how deep the bowl of the lamp is, if the wick reaches the bottom the blaze continues to burn, not only until the oil is all taken from the lamp but until the wick has become quite dry. The same rule or fact applies to the growing plant. So long as there is plenty of moisture below it will move up through the soil to the plant, keeping it in a perfectly healthy condition until the moisture is not only exhausted for several feet down, but the soil near the plant has become apparently quite dry. Then the plant begins to fade and wither.

Study well, by close observation, this question of percolation or getting water into the soil below. It is interesting and of great value.

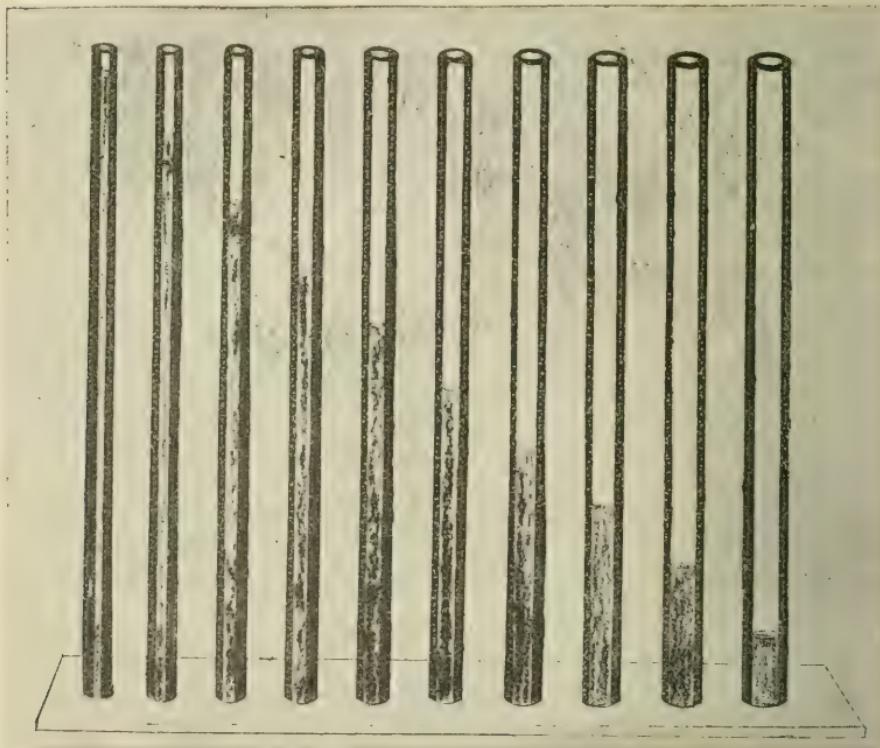
The deeper you can store the moisture the greater are your chances of securing a large crop.

A piece of ground that is moist for two or three feet down will take in the water of a heavy rain much quicker than ground that is dry. Here again is illustrated what moisture will do for us when we understand its ways.

CAPILLARY ATTRACTION.

The average experience of the eastern farmer has not demanded any knowledge of capillary movement of moisture in the soil, and the early experience of the inhabitants of the semi-arid belt did not call for thought respecting this matter. It is comparatively a new proposition. One of the best illustrations to show the real facts in connection with the movement of moisture in the soil, is that of glass tubes, which we have frequently used in lectures to illustrate this point. A tube about one-

tenth of an inch in diameter will lift the water about three-eights of an inch above the surface. We have ten, the largest a tenth of an inch in diameter, the others smaller, all varying in size down to as small a tube as can be made in glass, the smallest probably about one-hundredth part of an inch. In this the moisture will rise about six inches above the surface of the water in which the tube is placed.



Cut No. 9, Capillary movement of moisture illustrated.

The first careful study of the rise of the water by capillary tubes was made by Hauxbee nearly two hundred years ago, but history shows that the phenomenon was known to Leonardo de Vinci, the famous artist, who lived between 1452 and 1519. Notwithstanding the large amount of careful study which these phenomena have received even during recent years, we are yet in the dark as to just how the energy which forces the capillary fluids to move is transformed into current motions, but all who have studied the matter scientifically are agreed that it is in some way brought about through the surface tension of liquids. Capillary movement is somewhat like electricity. We know its existence,

we see its effects and have learned something of the various conditions under which its power may be utilized. Capillary movement of moisture, like electricity, has its field of usefulness, and it is now quite apparent that this force within the soil performs a most important office in soil physics.

Aside from the interest which the intelligent farmer will take in this movement as a natural law, it should be thoroughly understood for the especial reason that by capillary attraction the stores of water conserved in the soil below the root bed are gradually lifted up to the roots, as the plants may need the same for their sustenance and growth during a period of drouth. It is by the process of first making the soil near the surface firm and compact and then subsequently, by frequent cultivation as in the Campbell system, holding and storing all the rain waters in the stratum of soil below, that this wonderful movement of water upward by capillary attraction may take place and the growing crops be nurtured and matured.

By the proper preparation of our soil, that is, the fining and firming of the portion necessary for the root bed, experience has demonstrated that we do increase the power of capillary attraction or the more rapid movement of the moisture from below up. In this soil condition we have one most favorable to the free and rapid development of root growth.

If we can comprehend just how many stalks of corn, wheat, barley, or potatoes can be supplied by this movement to its full demand per square foot or square yard of surface soil, then with our blanket of loose soil spread over the surface to prevent any loss of this moisture so that the roots can take it all in, we have obtained a very desirable condition. These facts, when fully comprehended, must and will make of this great semi-arid belt the best and most desirable farming country we have in the United States.

That the fining or compacting, or any manner of reducing the spaces between the particles of soil does actually increase the movement of moisture is very clearly shown by the investigations of the condition of the soil beneath a horse foot track, or where a wagon has passed over a plowed or otherwise pulverized field. Where the soil lies somewhat light and loose to the eye it is apparently dry. Where the particles have been compacted by the weight of the wagon, or the horse, a much larger per cent of moisture is perceptible. Simple facts like these should not be passed over without a consideration of what they mean. The remarkable uses of electricity have been brought about by observing even simpler facts and conditions than these. The development of steam power and the vast amount of labor that is performed by it to-day, is the direct result of the simple observation of a boy, who placed a cork in the nose of the tea kettle, thus stopping the discharge of steam, when he soon discovered that the cover would frequently lift up by force of the steam

and allow the steam to escape. By holding the cover down he discovered the power. The simple facts with reference to the movement of moisture in the soil have already been proven to mean a great deal and eventually will reclaim the great semi-arid west.

With the fact that the moisture can be stored in the ground and there controlled and made available to the plant by the aid of capillary attraction, with such results as have been indicated, what are the possibilities of this great semi-arid belt? No one who has ever passed over this country, or remained in it for any length of time, has ever discovered any objections outside of this one fact, that crops and trees have not been successfully grown. All agree that the climate is most magnificent, the soil exceedingly fertile and very easy of tillage. The condition of the majority of the soil in the eastern states, that is, its composition and formation is such as to not be susceptible to the remarkable effects of capillary movements of moisture that are shown in the great semi-arid belt. It is undoubtedly due to this fact that so little attention has been given to this question until recent years. Capillary attraction is known to us and is illustrated by sponges. A sponge is moistened, then compressed, until all the possible water is pressed out, then drop the corner of the sponge into the water, and water is seen to immediately climb up through the entire sponge. The finer the sponge, the more quickly is it filled. This is an illustration that we used some years ago, which is exceedingly clear and quite convincing. The lamp wick is another illustration, as the oil is consumed from the end of the wick, more is at hand, and it gets there by no other power than by capillary attraction.

Study these three points carefully —Percolation, evaporation, and capillary attraction; they will be found more interesting the more the reader and investigator understands them, and when fully understood, the question of soil culture will be much better appreciated. You will then comprehend why the plowing should be reasonably deep and the under portion made fine and firm, while the top should be fine, but loose and dry.

AIR AND ITS IMPORTANCE IN THE SOIL.

Air in the soil has not received the attention and study that its importance demands as well as the fact that the mechanical arrangement of the six to eight top inches regulates very largely its availability.

Because we have seen it constantly demonstrated we know the necessity of water in the soil for plant growth, but it is not so easy to comprehend the material value to the plant of air in the soil. We cannot see its effect in anything like as broad a sense as we do the water, yet its presence in proper quantities in the soil and about the roots of the plants is just as vital to its life, health and growth as water.

Water without air and its component parts is worthless; air without water and its component parts is equally valueless to the growth and development of all farm crops.

Consider the subject carefully. How many times have we seen a field of wheat, corn or oats, possibly half-grown, and noted that in some depression the crop was ranker in growth and also a darker green. If a rain of considerable magnitude comes and the depression fills with water and remains there for some days, the plants that seemed to have the advantage before the rain now begin to lose their dark healthy green color; if the water remains long enough over the surface a yellow cast becomes apparent, then a brown and finally it dies. This is because of a lack of air at the roots.

In our experiment work we have observed some very marked conditions and results. We find that the air may be shut out by the forming of an almost impervious crust, either on the surface or beneath a soil mulch. The most marked effect of this crust was brought out at the Pomeroy Model farm, Hill City, Kansas, in 1901, during an extremely long dry period in mid-summer when for nearly three months almost the entire country experienced one hundred degrees of heat, at times the thermometer running even higher, without any rain. Because of wheat harvesting and other pressing work, the orchard was left from fifteen to eighteen days without cultivation. During this time a crust had formed under the mulch which we had kept fully two and a half inches in depth. The crust was nearly one inch thick and was so dense that the air was almost completely shut out. This crust was caused by the mulch becoming so heated through the direct rays of the sun that the moisture in the firm soil just beneath formed a vapor and passed off through the pores of the mulch, to a degree moistening the mulch, and allowing enough capillary attraction, which together with the heat, permitted much of the moisture to be lost by evaporation. This resulted in bringing up much magnesia, alkali, salts, etc., in a soluble or dissolved condition. When this soluble matter reached the point in the soil near the surface, where the moisture was transformed into vapor by the intense heat, it became a solid and these minute particles gradually filled up the pores in the top of the firm soil.

Our attention was first called to this on returning after an absence of four days from the farm, by noting the fact that the foliage of the trees was losing its dark green color. To ascertain the reason for this, after finding that there was ample moisture beneath the crust, the experiment of double-disking one-half of the orchard was tried. The disk was set to cut as deeply as possible, thus completely destroying the crust. On the morning of the fourth day there was a perceptible difference in the color of the leaves in this half of the orchard. In seven days the trees in the disked portion had resumed their healthy dark

green color, while the undisked portion had become still lighter in color. The balance of the orchard was then disked. Although the extreme weather continued four weeks longer, the leaves of the whole orchard resumed their fine, deep green and new growth was apparently rapid.

Similar conditions have since been noted in wheat, oats and corn, with same results from similar treatment, all pointing to the fact that both the growth and yield of crops may be very materially diminished by shutting the air from the roots of the plants.



Cut No. 10, Showing effect of shutting air from roots.

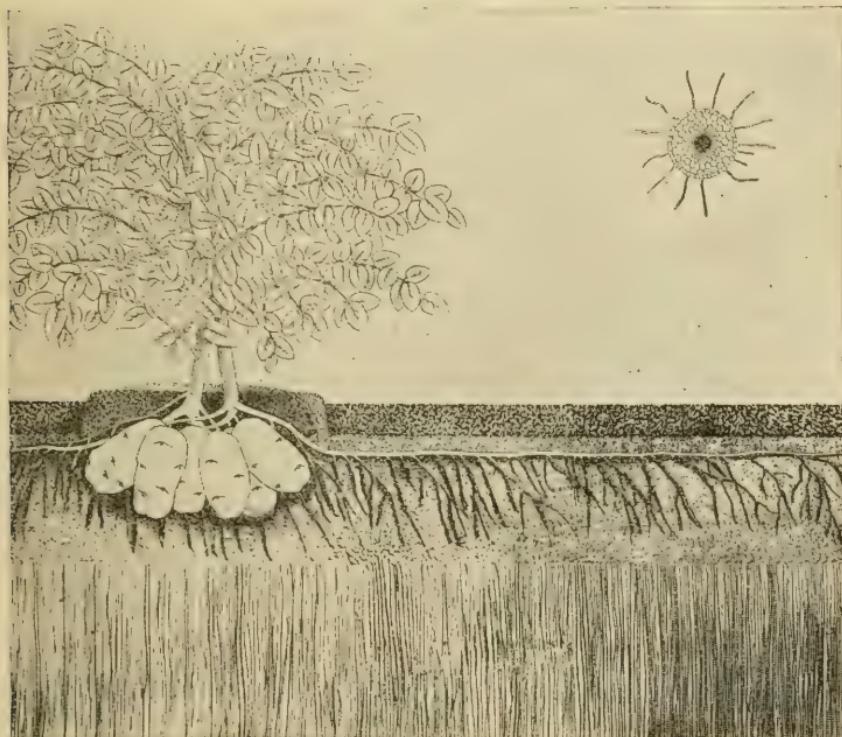
To illustrate more fully the effect of shutting the air from the roots we take the above cut from Goff's book, *Principles of Plant Culture*.

To make this test practical, two glasses were filled about half full of soft water, then two slips of the same kind of a plant as near alike as could be selected were placed in the two glasses and then a thin layer of olive oil was put upon the water in one glass to prevent the air reaching the water, the glasses placed in a warm light place; in a very few days live healthy roots are seen developing from the slip in the glass without the oil while the oil covered not only shows no roots but the leaves soon begin to wither. While it must be remembered that slips from any and all trees or shrubs will not do this, only such as willow, nasturtium, or wandering jew, etc. Yet it demonstrates clearly and beyond a shade of doubt that the air plays a very important part in the growth and development of roots and plants.

CULTIVATION.

No question connected with soil culture has received more attention, and has been more thoroughly discussed than that of cultivation of corn, potatoes, and other growing crops. In the past few years we have heard much about shallow cultivation. In fact it seems to be the prevailing idea, but there is danger in too shallow cultivation. Especially is this true in the higher altitudes where the atmosphere is drier. Here a deeper mulch is necessary to prevent loss of moisture by evaporation.

It needs no argument with the average farmer today to persuade him that deep cultivation with the old long pointed shovels is not the thing. Shallow cultivation is not, however, well understood. There are many important points not generally observed. In cut No. 11, we show a hill of potatoes which has been grown by shallow cultivation. It is proper to add that this ground was first plowed eight inches deep,



Cut No. 11, Shallow Cultivation.

having been previously disked, the plow followed with a sub-surface packer, and the whole portion made thoroughly fine and firm. In securing this illustration, the lateral roots of many different hills were washed out. The main roots running from the stock were almost invariably found to have traversed in quite a uniform distance from the surface of moisture: the little branches running out from the main roots taking various directions, some lateral and some down.

The illustrations quite perfectly shows all these important facts. Notice the two and a half inch mulch, and the very fine, uniform condition of the balance of the furrow or plowed portion, where may be seen numerous roots. This represents a hill of potatoes taken from a field grown on our farm in Brown county, South Dakota, in 1894, when thirty-two acres of high, level prairie produced an average of one hundred and forty-two bushels to the acre, and this in a season when almost all crops throughout the entire semi-arid belt were ruined by the extreme drouth.

In cut No. 12, we give another illustration of potatoes grown under other conditions. This ground was treated practically the same as that show in cut No. 11, but deep cultivation was applied, and less frequent. This field was cultivated three times, cutting fully four inches deep, which resulted in destroying nearly all the main lateral roots, while the other field was cultivated eight times, cutting about two inches. The difference in the result of the two crops was attributed directly to the treatment of the ground after planting.

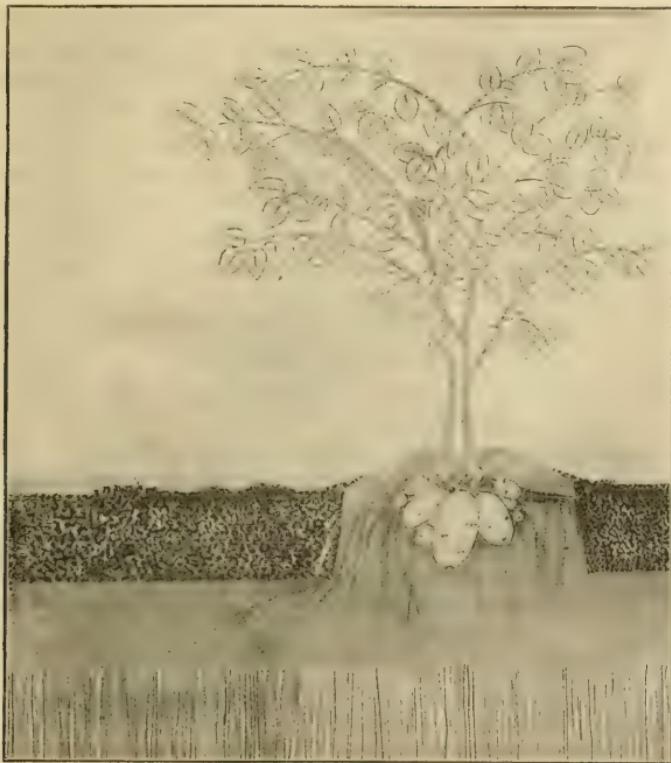
The main point we wish to show here is that time and manner have even more to do with the result of the crop than the kind of cultivation. If you would secure the greatest possible benefit from the labor given over to cultivation you should first provide yourself with some fine-toothed cultivator, so that the soil may be all thoroughly fined, leaving the surface of the firm soil beneath as near level as possible. Then, great care should be taken to catch your ground in proper condition. It is true there is but little time after a rain that the ground is in the best possible condition. This is the time when the free water has all percolated below, and the soil to the depth which you wish to run your cultivator, is simply moist—neither very wet nor very dry. In this condition the little particles seem to readily separate, one from the other, then your stirred soil is composed of an innumerable number of little, minute lumps, forming a mulch that gives you the highest degree of protection. A mulch made when soil is in this condition will never blow.

If the soil be too dry it breaks into large lumps which not unfrequently lay in such manner as to direct columns of air through the large spaces between them down to the solid and firm soil beneath, causing much loss by evaporation. It is needless to mention the difficulty arising

from cultivating soil that is too wet. When worked it becomes what is known as "puddled," and then when dried it becomes hard as brick and a heavy rain is required to even dissolve the lumps so that they may afterwards be pulverized.

SAVING WATER BY CULTIVATION.

There are two vital points in regard to the successful growing of crops in the western country. The first is the importance of getting all the water possible into the ground, and second, using every possible means to conserve or retain it there.



Cut No. 12. Deep cultivation.

The importance, or value, of a little additional water is shown by the effect of snowdrifts that may form on the field from any cause. The increased amount of moisture that seems to find its way into the soil when the snow melts invariably makes itself apparent in the growing crop as soon as a dry period begins to effect the crop in the least. At these points the crop always holds out longer, sometimes carrying

the crop over to another good rain, which results in maturing an unusually large yield on these places, while the balance of the field will not yield to exceed one-half or one-fourth the amount. Thus a gain in yield of wheat of probably ten bushels to the acre is the result of perhaps not over one-half inch of additional water that had percolated into the ground. The enormous evaporation from our fields under favorable conditions is not in the least comprehended by the average farmer because he has no means of readily testing and proving.

Under the heading of Evaporation, we have given the results of some experiments by Professor King of the Wisconsin Agriculture college, showing the rapidity with which moisture will rise through the soil by what is known as capillary attraction, reach the surface and pass off in vapor into the atmosphere in a single day. Not until the farmer begins to grasp the vital importance of keeping even a little additional water in his soil can he be expected to use all due diligence in preventing this evaporation. This observation of the farmers throughout the semi-arid west, during the growing season of 1901, especially Kansas and Nebraska, ought to be amply convincing with reference to the value of stored water in the soil. There were frequent remarks during its prolonged and severe drouth of the mid-summer with reference to how the corn continued day after day, and week after week, contending against this extreme heat without rain, without showing any apparent effect of drouth; but this was simply the direct result of the unusually heavy rains in early spring that percolated down into the soil, in many instances eighteen inches to two feet deeper than usual, and there acting as a reserve, continued to return by capillary attraction and feed the corn plants and other grain until it was exhausted. In this same chapter on Evaporation we make mention of several instances where the early disking of the ground resulted in retaining a sufficient amount of additional water to carry a crop of corn through, increasing its yield in some instances as high as twenty bushels, which was not secured in adjoining fields, not disked, simply because the moisture was allowed to evaporate by leaving the surface hard and compact, as is always the condition after a heavy rain or snow.

To be successful the farmer must grasp the full importance of doing all his work just at a time when the condition of the soil is best adapted. The idea that by plowing to-day we may get ten bushels of wheat to the acre, when if we plowed the ground four days later we would get fifteen bushels or vice versa seems rather ridiculous. While this statement and the figures used, may in most cases be a little strong, yet it is a fact that the average yield of a field is frequently increased or decreased quite a per cent by a few days variation in the time the work is done. This is especially true with reference to cultivation. I have in mind a case near Fairmont, Neb., where the phenomenal difference of fifteen

to eighteen bushels per acre was made by cultivating a part of the field before a heavy rain of nearly five inches and the balance of it after this rain. The reason of this remarkable difference was simply what we have been dwelling upon, the result of retaining a large per cent of moisture by the soil mulch produced by the cultivation after the rain, that was lost from the balance of the field by rapid evaporation. This occurred in July, and was the last cultivation preparatory to what is called laying the corn by. The rain was a very heavy one.

The part of the field that was cultivated previous to the rain was left with the thick compacted crust made by the heavy fall of water, which resulted in dissolving the loosened soil and settling it very close, thus leaving the surface in the best possible condition for a rapid movement of moisture to the surface and evaporation. Under the head of Capillary Attraction we have explained this more clearly. The portion not cultivated previous to the rain was gone over as soon after the rain as conditions would permit, thus producing a perfect protection to the moisture below, and bringing about the remarkable result referred to. While these cases cited seem like extreme instances, under similar circumstances you can look for similar results. When the reader begins to understand the direct effect of these conditions it will then be quite clear why a light crop was secured when a good crop might have been harvested.

AS TO TIME OF CULTIVATION.

The proper time for cultivating a field is one that cannot be fixed without much thought, observation, and judgment by the farmer, especially if he would get the best results. Always cultivate immediately, or as soon after a rain as conditions will permit you on the field, and the soil is sufficiently dried so that it will not adhere to the cultivator teeth, or tools used. We do not mean by this that the soil should be absolutely dry on the surface. It is an error to wait for that time, for the moment the surface is apparently dry the crust begins to form. It is desirable to catch the ground just before this time when all the soil is simply moist and then there is a free and ready separation of all particles. In this condition the cultivator runs the easiest, the mulch made the finest and lies up light and loose. If the soil is a little too wet it settles, and not infrequently forms absolute and perfect connection with the firm soil below, steadily carrying moisture to the surface. If too dry the cultivator produces an imperfect mulch that gives us but little protection.

Another and very important idea is that every moment's delay after the soil reaches the proper condition causes you to lose water very fast. It is at the rate of a quart or over per square foot per day providing it is clear sunny weather, and even more in case of heavy south winds. The more intense the heat the more frequent it is necessary to cultivate.

A very good rule is to watch the condition of the firm soil just beneath the loose mulch or cultivated portion, and whenever the surface of this firm soil begins to show dryness it is high time to commence cultivating again.

We cannot impress this point more fully upon your mind than by referring back to that part of Chapter X, which tells of the crusting of the orchard on the Pomeroy Model farm during the extreme dry period of 1901, and its effect upon the growth of the trees.

We had a similar experience, but more clearly illustrated, in the cultivation of corn in Cheyenne county, northwest Kansas, in 1898. This demonstrates very clearly the great importance of being exceedingly cautious, not to let any crust form under the mulch. We are of the opinion that many corn crops have been seriously injured by that condition, when with no more available moisture the crop would have come out all right had it not been for this crust.

KEEPING THE MULCH IN CONDITION.

There are many important reasons why great care should be taken to keep the mulch in perfect condition and prevent the loss as far as possible of any moisture by evaporation from the surface of the soil. The following paragraph taken from Professor King's book on "The Soil" conveys some important information along this line. We quote this because it bears the figures of his own practical observation at various depths in the soil, showing the effect not only of the surface soil getting too dry but of light showers. He says:

"When the surface soil has its water contents reduced so the upper six to twelve inches are beginning to get dry the rate of capillary rise of water through it is decreased and it begins to assume the properties of a mulch. But when this condition has been reached if a rain increased the thickness of the water film on the soil grains without causing percolation the capillary flow may be so certain that the surface foot draws upon the deeper soil moisture at a more rapid rate than before, causing a trans-location of the lower soil moisture, the deeper soil becoming measurably drier soon after such a rain than it was before, while the surface foot is found to contain more water than has fallen upon it."

He cites experiments as proof of this important principle. Some of his experiments were very interesting and instructive, showing that by wetting the surface capillary attraction was so increased as to show that moisture had moved up from the fourth and fifth foot below.

This emphasizes the fact that the tiller of the soil should understand these conditions that he may know just what to do to get the best possible yields.

In closing this chapter we venture to repeat that we may emphasize some things taught.

Winter wheat will not winter-kill in firmed, moist soil, while in loose soil it frequently thins out or kills out entirely.

A fine, firm root bed, with a loose surface or mulch, is a condition that will withstand the extreme dry periods longest without any injury to the plant.

Study well the question of thoroughly pulverizing and packing the lower portion of the plowing; a full understanding of its importance means many dollars, because it means a larger crop result.

Sub-surface packing increases the moisture in the lower portion of the plowed ground and induces decomposition of the weeds, stubble, or manures that have been turned under, thereby adding humus, the all important soil ingredient for rapid plant growth, as well as enabling the plant to withstand drought.

If you would get your soil to a condition of fineness and firmness, do all your work to that end when the soil is just slightly moist, for it then plows better, packs better, and cultivates better. Do not go to work on plowed ground that is dried to the bottom, whether plowed in good condition or not, and expect in any way to get the lower portion of the furrow in good condition. You may improve it. The closer you keep to the plow the better you can pack the under portion.

BARN YARD MANURES.

It needs no argument to prove to the eastern farmer in the more humid sections of this country, that there is great value in the use of barn yard manures. In fact, in most sections of the east every opportunity possible is utilized in increasing the quantity. In the West, or more especially in the semi-arid belt, farmers have come to look upon this question in an entirely different light. Probably in the entire belt at the present time a much larger per cent of these manures are either thrown into a draw or burned up. This is all wrong. There is no section of country where the soil would respond more liberally and for a longer period of years after the application of manure than here. The difficulty lies in the manner of applying. The dryness of our atmosphere and the frequent long periods without rain is not conductive to nitrification or decomposition, consequently in our early experiences in applying it to our fields, more or less straw and coarse matter in almost a perfect state of preservation had to be used. With our light, loose, loamy soil there is not sufficient weight to press this coarse matter down solid when plowed under, consequently the open, porous condition underneath, the detrimental effect of which is well known, resulted in burning

the crop and producing weeds. To throw coarse manure on the ground leaving many bunches, then plowing it under without special care in packing, is of little value. We have had the best results, in short, have never failed in getting good results, by putting it on with a manure spreader, then with a sharp disk double-disk the surface, mixing it to a considerable extent with the top three inches of soil, then plowing six or seven inches deep, using a rod on the beam to turn everything under, following the plow with the sub-surface packer, which would result in packing the soil and manures firmly in the bottom. With slight moisture under these conditions decomposition quickly takes place. In our early experience in Brown county, South Dakota, in the year 1882, we applied a liberal coating of barn yard manure, plowed it under, and worked it down as best we could after the manner usually practiced in old Vermont. The rainfall during that season was quite liberal and timely. The piece, about five acres, was planted to corn and well cultivated, with such good results, that we decided to treat the manure question with the same care and economy as we were wont to do in the East. The same plan was followed out in 1883, with a total loss of all the crops which were planted on that ground. A small attempt was made again in 1884, with the same poor results. For several years after this we followed the usual plan of the western farmer, of hauling it out and using any possible method to get rid of it. But the remarkable results each and every year from the field where the manure was applied in 1882, was too convincing of its value. For ten consecutive years this entire quarter section was put into wheat. Every year in the early stages of the growth of the wheat, the shape of this five-acre field, which was in one corner of the one hundred and sixty acres, was perceptible both in the color of the wheat and the development of the stools, and almost invariably at harvest time the grain on this little piece would be from four to eight and ten inches higher than the balance of the field, and yielded invariably from fifty to one hundred and fifty per cent more. With much study along these lines, and several experiments, to find out why such remarkable results were obtained from this field and why we could not succeed in later attempts, we were finally able to solve the problem fully. It is simply a question of mixing the manures into the soil as much as possible, and then firming the under portion of the furrow slice, thoroughly packing manure and soil, followed with careful cultivation, when the same results may practically be attained any year that were secured in the seasons referred to, when we had the unusual amount of rain scattered along at proper periods at just the right time to produce decomposition. The peculiarity of the formation of our soil is such that manures, when properly applied, very materially aid us in carrying our crops through the dry periods and preventing the serious effects of the drouth, for the simple reason that the humus, which is

the complete decomposed vegetable matter, very materially increases the water holding capacity of our soil. The more humus we have in the soil, the greater is the number of particles, consequently the greater amount of surface to hold water. It also aids in the movement of moisture through the soil, and in the encouragement and development of root growth.

When barn yard manures are properly applied to the prairies of the semi-arid belt, their effect upon plant growth is noticeable much longer than in the east, where the greater rainfall has a tendency to wash the humus below. This trouble of washing out is especially perceptible in the gravelly soils of New York and the New England states. There is another advantage of the semi-arid belt which will be appreciated when these facts are better understood by the masses, for our observations so far clearly show that manures are even more valuable here than in the East, not that our soil is not fertile, but the more humus we have in the soil the more water will each square inch of soil hold, and consequently our crop is safer and less liable to suffer from drouth. There is but little expense attached to an experiment to ascertain the correctness of our assertions on this subject, and were you to make them, you would find more and surer profit from them than from government bonds. The sub-surface packer is a very valuable tool in securing immediate results from manure. See cut No. 2. This shows how the manure would be compacted in the bottom.

Professor Goff in his book on principles of plant culture, says: "Much of the benefit of manuring undoubtedly comes from the increased capacity it gives the soils for holding and transmitting water."

Professor King says in his book on soils, that in three years' experiments with barn yard manures he found "That for manured fallow ground the surface foot contained eighteen and three-fourths times, or four thousand and eighty-seven gallons more water per acre than adjacent and similar but unmanured land did; while the second foot contained nine and one-fourth tons and the third six and one-third tons more water, making a total difference in favor of the manured ground of thirty-four and one-third tons or eighty-five thousand gallons.

We would advise, where it is possible, to plow manure under in summer tilling fields and in doing this it will be found that less seed is needed for best results.

THE MANURE SPREADER.

While the manure spreader is a very valuable farm implement from a time saving standpoint, yet its great value lies in the fact that the manure is thoroughly torn into small pieces and very evenly distributed over the surface of the field. It will pay for itself in a short time providing the farmer will use great care in mixing the manure

with the soil, plowing it under at a fair depth and then firming the soil with a sub-surface packer. It only takes a little manure per acre and a little intelligent mixing and preparing of the soil to easily double the present average yield.

CORN.

In the eastern states among the hills of New York and New England, a large amount of time is given to the preparation of the soil. Experience has taught them that without this, crops are light. Barn yard manure is used freely, and two, three, or four dollars worth of fertilizing per acre is not uncommonly necessary in order to secure good crops. Professor Bailey of Cornell University, Ithaca, N. Y., has well said that no after cultivation can make amends for a poor job of preparation. This applies just as much to the semi-arid belt as it does to the eastern sections of the country. In Illinois the soil is more fertile and rain usually ample, so that no fertilizers are required and when the rains are ample and timely two or three ordinary cultivations produce a good crop of corn. But even there they are beginning to learn the value of conserving the water by more frequent cultivation, because of dry periods that are liable to come at any time. With us in the semi-arid belt more attention must be given to the preparation of the ground. We cannot depend upon heavy rains to aid us in dissolving and settling our soil, consequently we must give close attention to every part of the work. The first thing in order is the early disk ing which should be a double-disking in order to thoroughly pulverize the surface, bearing in mind that every act must be to store and provide the greatest possible amount of water in the soil. Early disking covers the two important points previously referred to, that of preventing the evaporation and opening up the surface to receive the later rains. This done, we simply wait for the proper time of further preparation and planting, always being in readiness, however, to loosen the surface at any time, should we get a rain of any magnitude. There is some diversity of opinion as to whether the check-rower or lister is preferable, more particularly in the lower altitudes. We favor the lister in the higher altitudes, or in the northern sections, where the nights are cooler, which results in heavier stooling or suckering. These additional shoots are very detrimental to the corn crop, especially so, should we have a dry season, but for the more humid sections we still favor the check-row planting especially on rolling land.

THE LISTER.

The lister has one advantage that is especially desirable. By filling the furrows about the time the shoots begin to show and thereby covering them up we may destroy them completely, which is easily and quite readily done. Another advantage in listing in the more arid sections is that of getting the roots deeper into the ground. The higher the altitude and the drier the atmosphere, the deeper is it necessary to cultivate in order to produce a deeper mulch to prevent evaporation. In using the lister on ground where the moisture has been carefully preserved by disking and harrowing in the early spring it is quite important to follow the lister with some tool to thoroughly pulverize the moist soil that is thrown up as such soil soon assumes a dry and very hard condition which is afterwards hard to manage.

The best tool for this purpose is the weeder, the long, flexible teeth lap down on the side of the furrow or ridge as thrown up between the rows and quite completely pulverize the large clods that are thrown up by the lister, leaving a perfect circle with a nice fine mulch over the entire surface. This puts your ground in magnificent shape, especially in the sand loam soils of the semi-arid belt, so that you can continue the use of the weeder by going lengthways of the ridges and completely destroy the weeds before they assume any size, keeping your mulch in perfect condition to prevent evaporation, going over the ground after each rain as in the cultivation of other crops, watching the condition very closely in order that you may catch the ground just when slightly moist before the crust has begun to form. This does away with the weed cutting idea.

On the Kilpatrick ranch, in Chase county, Nebraska, in 1903, two hundred and seventy acres of listed corn were handled in this manner. The weeder used was the combination weeder and harrow made in sections the same as the common steel harrow. Enough sections were used to cover six rows of corn and the entire field was gone over four times before any other cultivator was used and the corn was then about eight to ten inches high. The suckers or stools were from two to five inches long. A two-row riding cultivator with two wide shovels on each side was then used throwing the soil from the ridge over the suckers to cover them up and practically leveling the ridges down. A few days later it was with considerable difficulty that a sucker could be found, in fact with care and catching the corn at proper height the suckers can all be destroyed. The cultivator was followed with the weeder which practically leveled the surface. The corn was now ten to fifteen inches high and scarcely a broken stalk could be found owing to the fact of the flexibility of the teeth and that the drag or weeder bars were seven inches high. The field was gone over five times with a weeder

that took in six rows, costing less time than to have gone over once with a one-row cultivator and once over with a two-row cultivator. This made the total cost of six cultivations equivalent to less than once and a half over by the old plan. The corn was harrowed five times and made over forty bushels to the acre. Only twelve miles east of the Colorado line many similar conditions and results can be given.

In growing listed corn we do not believe in very deep listing, but in thorough cultivation from early spring until the crop is put in, then consider fully that ample moisture and air must be in the soil and that weeds growing in a corn field live on your best corn.

CHECK ROW PLANTING.

In planting with the check row planter it is important to plow the ground as early as possible. Here again, the early disking comes in with its all important results to prevent the evaporation, holding your ground in perfect condition for rapid percolation of the later rains. This is advisable because you can get onto your ground with the disk when at a proper depth to plow it would be too wet. Then again, you can cover the field quicker if you have a broad gauged disk than with the plow. It also enables you to get your soil in much better physical condition, than would be possible if the ground were allowed to dry out. The plowing should be followed up soon after, but remember this point—if you have been particularly persistent in preventing this evaporation by the disking your ground is in perfect condition to plow, even though you have considerable dry weather later on in the spring. The soil will roll up in a moist condition, and is susceptible to the best results with the packer or any other tool. Follow the plow closely with the packer, at least every noon and night, if you have one.

There are few places where the sub-surface packer turns the profit it will in following the plow in preparing a field for corn. An experiment on the Burlington farm in Phelps county, Nebraska, in 1904, where a strip of land in a field being prepared for corn was left without packing, the following facts were observed: Germination was four or five days slower; the stand of corn much less uniform and the final yield per acre fully fifteen bushels less.

After your ground is turned over and the necessary work done to pulverize the surface, watch closely the condition. Whenever any rain comes, even though it only wets through the mulch or loose soil on top, it is necessary to immediately stir it to dry it out.

The importance of quick work after the surface has been moistened, even by a slight rain, cannot be too strongly urged. See Chapter IX. In the use of the check row planter the difference in the time of germination, the rapidity of the young plant in ground prepared as outlined

under the head of plowing and sub-packing, as compared with corn put into ground in the ordinary manner of preparing is interesting.

The growth of roots as shown under the head of root development is also interesting. Do not put too much in seed. There are unquestionably many instances where very light corps of corn have been secured from too much seed. Had there been one-half as many stalks growing there would have probably been two or three times as much corn. I have frequently heard the remark: "If you don't put in the seed you can't get the crop," indicating the crop was gauged by the quantity of seed. This is another mistake and is beginning to be more generally understood. The strongest evidence along this line is found in some experimental work which we conducted in 1897, where eight ears of corn were raised from one single kernel. Seven of these were well developed ears, the eighth having corn about half the length of the cob, both the upper and lower ends of this cob being bare of corn.

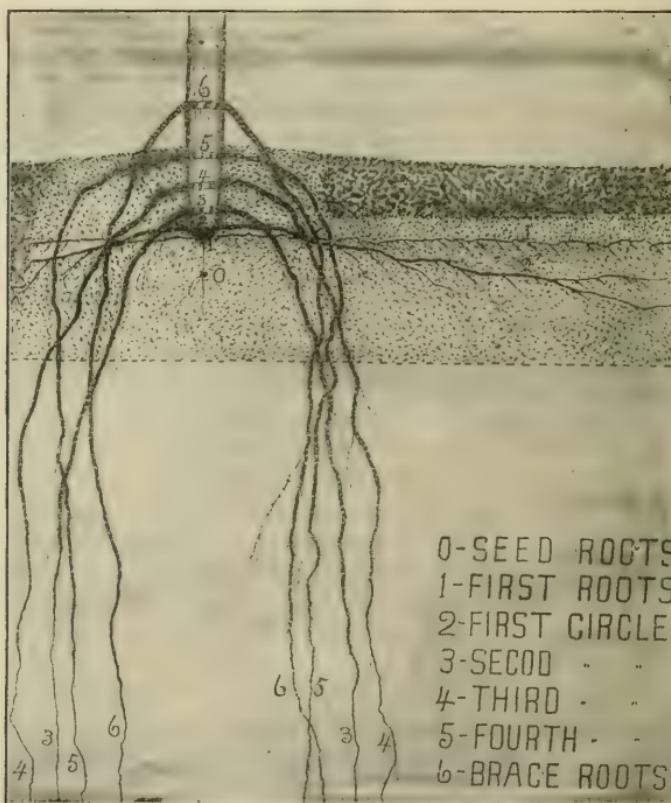
AMOUNT OF SEED NECESSARY.

One fact may not be generally known, that every healthy corn stalk starts from five to ten ears. Now the development of these ears depends entirely upon the physical condition of the soil and an ample supply of available soil moisture, air and plant food at all times. It is true there are instances, or conditions that might exist by which more corn might possibly be got from two, three, or four stalks in a hill than one. These would be rare cases, and where by extreme heat the demands upon the supply of moisture and plant food might suddenly destroy the vitality, or life of all the ears that were started on the corn, except the top one. Then a sudden and liberal rain immediately replenishing the soil about the roots with the necessary moisture which would immediately increase the available supply of plant food and push to completion the single ears left on each stalk, when we would have two, three or four ears to the hill as against one ear if we had but one stalk. Then again should the dry period continue longer without any rain we might loose all the ears, because the demand for moisture to supply the growth and development of two, three, or four stalks would be just that much greater than for one stalk, consequently the one stalk could endure the drouth longer without suffering, and probably reach the next rain when ample moisture would mature one or two good ears as against none at all with a larger number of stalks.

DEVELOPMENT OF THE ROOTS.

It will be seen from these facts that it is possible to secure as large a yield from one kernel in a hill as from three kernels in a hill, and in the semi-arid belt much more probable, although where ample moisture is stored and conserved and soil well prepared we favor two kernels to

the hill. In cut No. 13 we show a single stalk of corn and the general direction and development of roots. This illustration was made from several careful investigations of the location and development of corn roots. In the right hand corner you will note the figures 0 to 6, each indicating the circle of roots, 0 indicating the first development, or from the germination of the kernel of corn, while No. 1 indicates the second growth of roots, which almost invariably is found to run very close to



Cut No. 13, Development of corn roots.

the surface of moisture. The depth of the early cultivation of the corn, providing we have no immediate subsequent rains to moisten the cultivated portion, largely regulates the location of these roots, therefore it is well to go slightly deeper the first time. No. 2 indicates the third line of roots, which is almost invariably found, although starting from the stalk a little higher, to make its way to a lower point beneath the line from which roots No. 1 seem to feed. These roots although only

shown in the illustration as being single roots running to the right and left as we look at the stalk of corn, yet there is an entire circle around the stalk running in every direction, providing the condition of the ground is such as to encourage them. Here one can readily see the importance of cultivating as deep the first time as in any previous cultivation, for these roots find their way out through the soil in the early stages of the growth of the plant. Roots No. 3, which is the second circle of roots, are what is properly known as brace roots. These roots like the subsequent roots 4, 5, and 6, find their course very largely straight down into the soil. They, however, convey but a small per cent of moisture and plant food to the corn. This being almost entirely the work of the roots shown by 1 and 2. Here in this illustration can readily be seen



Cornfield by Campbell System, 84 bushels per acre, Lisbon, N. D.

the serious results from deeper subsequent cultivation, which might result in cutting off many roots. We can also see the importance of all work as outlined under the various headings referring to the preparation and care of the soil being carefully carried out.

Here in this illustration is represented corn put in with the check row planter, the ground plowed fully seven inches deep, thoroughly pulverized and made firm. Now, supposing we have carried out the necessary work to have stored and conserved moisture to considerable

depth, five or six feet, with our plowed ground thoroughly pulverized and made firm, we have the best possible condition, as stated under the head of Sub-Surface Packing, for the three all important conditions which we so frequently mention. That of holding the greatest possible amount of moisture in the soil, a condition to promote the most rapid movement of moisture by capillary attraction from the sub-soil up into this finely pulverized portion. Also a condition most favorable to the development of roots and root hairs or feeders. Careful investigation of fields thus prepared after the stalks of corn have reached a height of three or four feet will show almost a perfect network of these little roots and feeders throughout the entire field. Scarcely a spot half an inch square can be found that is not permeated by many of these little hair roots seeking the moisture and plant food therefrom.

With our moisture in ample quantities below, as stated, and this perfect condition of soil and development of roots, the growth and development of a magnificent crop of corn now depends entirely upon the time, manner and kind of cultivation. It is not absolutely necessary that the farmer should have a specially fine toothed cultivator. The Eagle Claw cultivator, that carries four shovels on each side of the row, is probably the best in general use. Again we must repeat the importance of watching closely the condition of the soil, that as much of the work as possible may be done at the time, immediately after a rain when the soil is simply moist and the soil grains seem to most readily separate one from the other, as in this condition the most perfect and uniformly fine mulch may be produced.

BROAD-GAUGED CULTIVATORS.

From the fact that it is so extremely important to catch this ground at just the proper condition, a condition that does not long exist after a rain, it is apparent that cultivators on the broad-gauged plan must be produced by our manufacturers. A two or three-row machine is very important, that we may cultivate two or three times as much ground in the same length of time, and when the farmers come to understand the importance of rapid work and the demand is made, such tools will be produced, for Yankee ingenuity is prevalent in all of our big manufacturing establishments. Returning to cut No. 13, and the existing conditions as outlined, if the corn is not too thick in the ground, we never have had a season that a sufficient amount of moisture could not be held about these roots to produce, not only a fair crop, but a remarkably good crop. If the loose mulch on top, to a depth of two and a half or three inches, is first produced when the conditions are just right after a rain, and stirred just often enough during the long dry periods, we can practically prevent any loss whatever by evaporation from the surface. This accomplished, the perfect physical condition of our soil and complete

development of roots will take the moisture from below sufficiently fast to prevent practically any damage from extreme drouth, and produce a most magnificent crop of corn.

TIME FOR INVESTIGATION.

These illustrations, coupled with the facts referred to under the heading of Evaporation, where fifteen to even twenty bushels was added to the yield of a field of corn, where only a small part of the work here referred to was carried out, is certainly sufficient evidence to prompt many to make even a small test to find out the correctness of these assertions. If they are true, then it is folly for men to raise five, ten, or twenty bushels, when by a more careful and thorough plan of cultivation, forty, fifty, or seventy-five bushels might be raised.

Plenty of water in the soil makes plenty of corn.

No after cultivation can make amends for a poor job of preparing the soil for crop.

The deeper you can get the water stored down in the ground before planting time the surer you are to get a big crop.

Cultivate your corn at least once after the last rain. If you don't need the water for this crop you may the next.

Don't get the shallow idea too strongly fixed. Two and a half to three inches of fine loose soil is about the best condition.

Watch the first approach of spring and as soon as you can get into the field with your disk, go over your ground intended for corn. Nothing can pay better.

There is no work done, cost considered, that seems to go farther toward increasing the yield of corn than that of early double-disking. This is also quite true with reference to all other crops.

Never allow a crust to form under the mulch no more than you would on the surface. It will get there if you don't watch closely during times of extreme heat in long dry periods. Don't let weeds grow. Every weed means less corn.

EVAPORATION.

The principles and processes of evaporation are another thing of great importance to the farmer who lives in the semi-arid belt. In fact there is nothing more serious for the farmer than the loss of rain water by vapor, the direct result of the sun's heat and the hot winds. The remark is common in the semi-arid belt that we do not have rain enough, or if we had a little more rain it would be the greatest country on earth.

To all this we take exceptions. It is true that if we could always have just rain enough, at just the proper time, to enable us to grow mammoth crops without any special effort on our part, it would be very nice; but this is not true in any part of the country. In the more humid sections of the country crops not only suffer at times from extreme drouth, but it is not uncommon that fine crops are lost by too much rain after all the processes of growing and harvesting have been successfully carried out.

The real difficulty in the semi-arid belt is not a lack of rainfall, but the loss of too much by evaporation, and this can be largely controlled by proper cultivation, at least sufficiently to secure a good growth of crops every year. It has been demonstrated by careful laboratory and field work by Professors King, Whitney, Hillgard, and others, that seven inches of rainfall is ample to grow a good crop of any kind, providing the water is all utilized. Measurements and records by the government weather bureau have shown that in the more westerly portions of the semi-arid belt the average rainfall is more than twice as much as is needed, while a little farther east it is three and four times the necessary amount.

The usual difficulty, if such we may call it, is the fact that this rain does not always come just at the time the plants most need it. This is the reason crops have failed and the average investigator or observer of the existing conditions in this great belt has drawn the conclusion that there is not rain enough. We have lived in this belt of country twenty-six years, and have experienced all of the pros and cons, and ups and downs, that the country is heir to. Fourteen years of this time has been entirely spent in the study of the soil, the movement of the moisture in the soil, and that all-important question of storing the rain waters. Our experience in these fourteen years have been quite varied, but each and every year some new and important fact has been brought out, all leading to the one conclusion, that the rainfall can be stored in the ground and its evaporation prevented by a proper manipulation of the soil, thus enabling us to secure, not only fair, but remarkably good crops any and every year.

The present and most modern methods of irrigation have been the result of study along the same lines that we have been working, to-wit: that of conserving the moisture in the ground by cultivation after once thoroughly saturating by turning the waters in from the ditches. The most successful farmer today by irrigation, secures better results with one-fourth as much water as was used by the average irrigator some years ago.

The wonderful rapidity with which moisture rises by capillary attraction to the surface and is evaporated is not commonly understood. The most favorable condition for this rapid, upward movement of moisture is the natural condition found after heavy rains, when the surface soil

particles are dissolved and settled closely together. Professor King has conducted some very extensive experiments in ascertaining the amount of moisture that would evaporate from a square foot of ground in twenty-four hours. This work was accomplished by placing a metallic tube one foot square in a tank of water so protected that there could be no evaporation or loss of water, except through this tube. The tube was five feet long, filled with soil from top to bottom, and submerged into the water four feet, so the moisture to reach the surface to evaporate had to pass up one foot through the soil by capillary attraction. The rate of evaporation for ten consecutive days was a quart and a half of water to the square foot. The tube was then lifted one foot higher, making it necessary for the moisture to rise two feet by capillary attraction when the loss was a little over one quart. It was then lifted to three and then four feet and when rising four feet by capillary attraction the loss was a little over a pint to the square foot. This shows clearly why our crops may suffer so quickly even after we have had considerable rain.

The experience of the writer in his own work in 1894, demonstrated clearly these two facts: First, that moisture will evaporate very quickly when soil is left in its natural condition; second, that a large per cent of moisture can be stored in the ground. In that year there was no rainfall in the last of May or the month of June, and the average field was practically dry when the first rain came on July 7. At that time the fields were flooded by a rain of four and a half inches which came down quickly. In the fields where we were conducting experiments we had previous to this time got the moisture down nearly three and a half feet, and the surface was in the best of condition to absorb the fresh rain. In ten days the ordinary field was again practically dry. In such fields, owing to the great resistance of the dry soil, percolation was very slow and the extreme heat which naturally followed quickly evaporated all the water which had fallen. But the field we had been carefully cultivating and had prepared for just such an emergency, was found to have a moist soil over two and a half feet deeper than before, or down to a depth of six feet.

During the season of 1901, there were many demonstrations of the remarkable results following extra work done just at the proper time. A farmer near Fairmont cultivated once more after a heavy rain which came about the middle of July, after the farmers in that locality had "laid their corn by." This extra cultivation, which could not have cost over 30 cents an acre, added fifteen bushels per acre to his yield of corn. James Armstrong, of Phelps county, double-disked his ground early in the spring, then cultivated his corn once more than his neighbors, at a total cost not exceeding 60 cents an acre, and got twenty bushels of corn per acre for his extra labor. This may seem like an exaggeration, but the comparison was made between this field and an adjoining

field on his own farm not thus treated, as well as a comparison with the crops of his neighbors. Dozens of similar illustrations could be given of the immense value of this principle. If the work is done at the right time results are great.

Evaporation of the rain water on the great plains country has made many a man hopeless and homeless. Prevention of evaporation of the soil waters by proper cultivation means better crops, better homes, better people, happier children, and a better country.

Evidence from all over the semi-arid west proves conclusively that if every farmer had fully understood the theory and principles of conserving the soil water by proper cultivation, there would have been no short crop of corn in 1901 in that section of country. The excessive evaporation of the rain water all over the great plains country is the direct and sole cause of a greater loss to the farmers of that belt than any other one thing. Educate the farmers of the semi-arid belt to store, conserve, and utilize the rain water and we have paved the way for thousands more ideal farm homes and a higher state of prosperity than this belt ever experienced or the people anticipated. It is by and through knowledge of certain great fundamental principles of agriculture, and application of those principles to conditions which exist in this semi-arid belt and no place else in our country, that this region is to come into its own and be made indeed a veritable garden.

WHEAT.

In discussing the growing wheat it seems almost necessary to divide it into two headings, winter and spring.

SPRING WHEAT.

Spring wheat in the northern sections and on up into Canada, has become a very important crop. In preparing ground for this crop little attention has been given in the past to the all important question of storing and conserving the rain water. It has been simply a question of plowing at any time when the farmer was ready to plow, the seeding and harrowing likewise, without reference to the condition of the soil, or the storage of water. In the more arid portions of the wheat belt in the northwest there is no question but what summer culture commonly termed summer fallow, would be found exceedingly profitable. While we have thoroughly discussed this question under another heading referring especially to that of **Summer Culture**, yet its work is of such great importance, and the additional expense so little compared to results that we cannot

resist a repetition. If the work is properly done the returns are large. Begin first in the early spring, just as soon as the frost is out of the ground, and the soil sufficiently dry to permit of disking without the soil adhering to the disk, lapping half so as to thoroughly pulverize the surface, thus putting your ground in condition to prevent evaporation, as well as to admit of the rapid percolation of the early rains and you will be surprised at results. Keep the surface harrowed or loosened by the use of some tool to the depth of at least two inches, plowing in June or July, the time when other work is least pressing, to a depth of six or seven inches, following the plow closely with the sub-surface packer and let the packer be followed closely with the harrow, keeping in mind that all-important point of working the soil when it is in the best condition to most thoroughly pulverize, continuing this surface cultivation after the plowing through the entire season. In this work again the Acme harrow is most desirable because each time over it brings the soil from below up and to a large extent turns the soil from the extreme surface to the bottom of the portion stirred by the Acme. In this kind of work in the northwest, as well as in any portion of the semi-arid belt, it is very important to do this surface cultivating, whether it be with the common harrow or the Acme harrow, spring tooth or disk, at a time when the soil is in the best possible condition; that is, simply moist, not dry or wet. Then you have a fine even soil mulch composed of minute lumps, a condition you cannot get if the soil is dry or wet. It is when soil is in this condition that the particles seem most readily to separate, not simply into dust but these minute lumps made from slightly moist soil when dry will never blow.

Having had fifteen years experience in the northwest I am well aware of this blowing difficulty on the lighter soils, which can be entirely prevented by care with reference to the condition of the soil as above stated. It is very desirable in following this plan to keep the weeds entirely clean from the field. Don't for a moment encourage the idea that weeds are valuable to turn under, for there is so little value to them that it is not worthy of consideration, but the water drawn out of the soil by these weeds while growing is far more valuable to the coming crop. Watch it carefully. In the spring time try to catch this ground as early as possible with the harrow, Acme preferred, and put in your seed not to exceed one-half bushel to the acre. This quantity is ample. Read carefully Chapter VI.

If you will give close attention to this point you will simply be astonished at the results obtained. When a crop has been taken off, get on this ground as quickly as possible with the disk harrow. Double disking is exceedingly valuable. The small size disk, fourteen or fifteen-inch, set at a good angle will quite thoroughly pulverize the ground, but with the larger disk it is impossible to get a good condition without double-disking. Remember that the object is to thoroughly pulverize

the surface two or three inches, to not only prevent the loss of any moisture we may have below, but to have the ground in the best possible condition on the surface for the rapid percolation, or getting of the rain waters down into the soil. Lose no time after any rain in again loosening the surface, especially upon any ground that you may have already plowed. After the disk ing, plow and pack and harrow, as stated with reference to summer culture. Should you get any heavy rains late in the fall lose no time in loosening the surface to save the water, for you may need it the following year.

When spring time comes get over your ground as quickly as possible with the harrow, aiming if possible to do this before the surface gets dry, put in your seed, not too thick, and await its developments when it reaches the stooling point, which it will do early in the season if your ground is in the condition. At this point of growth, that is when the wheat is beginning to stool or sucker, go over your ground with a long toothed weeder. This will loosen the surface and destroy the weeds. The checking of evaporation by this cultivation will urge on your wheat when it will soon cover the ground then the danger of evaporation is much less. The rich prairie soils of the Dakotas, Minnesota and other sections of the northwest should produce thirty to forty bushels of spring wheat instead of five, to twenty and will if the soil is properly handled.

Don't think for a moment that you can get this rapid growth and early heavy stooling of the wheat unless your ground is thoroughly fined and firmed and you have held the moisture below, forming a seed bed in which there will be a rapid development of strong roots which is the direct result of prolific stooling. The use of the weeder or harrow, on wheat after it has begun to stool, or is three of four inches high, when your ground is loose and porous where the roots should grow is not always a safe proposition. The root development is so light that much of the wheat may be easily pulled up and destroyed.

WINTER WHEAT.

Winter wheat is a little different proposition from the spring wheat. Here again we believe when the farmer in the winter wheat belt has learned the value of summer culture and how it will not only greatly increase the average yield, but make a failure, so far as drouth is concerned, an impossibility, a larger acreage will be thus treated. The experience on the Pomeroy Model farm in the past four seasons, 1901 to 1904, inclusive, as well as many other fields in western Kansas and Nebraska, are certainly evidence that our ideas drawn from years of experience and observation are something more than theory.

They at least carry very strong evidence as to the value of this class of work, where by this very thorough and careful preparing of the

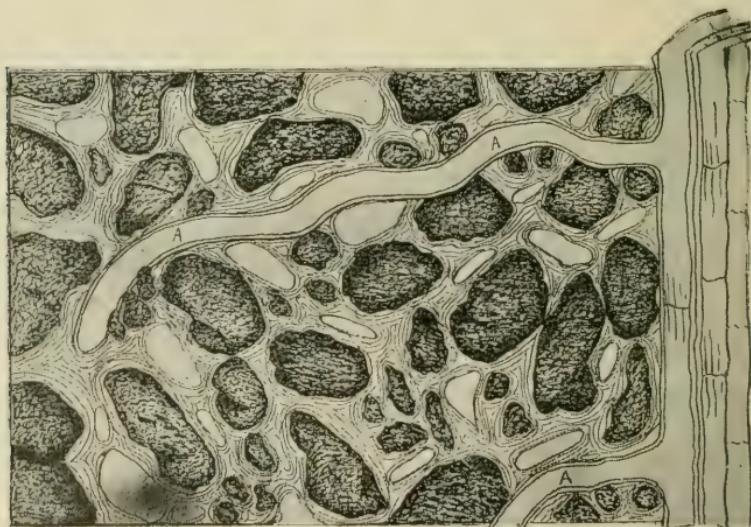
soil, having plowed about seven inches deep, followed our plow closely with the sub-surface packer, and the packer with the Aeme harrow, going over our fields immediately after the heavy rains or as soon as the soil was sufficiently dry to permit it, we had formed a fine, firm and very moist seed bed. Under these conditions twelve quarts of seed was found to be ample. Its germination was so quick and the rapid development of roots brought about by the very favorable physical condition of the soil caused the liberal stoeing, and in thirty days after seeding our ground was nearly or quite covered with the wheat. The immediate disking after the winter wheat crop is removed is of very great importance: as we have repeatedly said, it is of two-fold value, as it prevents the loss by evaporation of any moisture in the soil, and puts the surface in the best possible condition for the rapid percolation of later rain waters. The plowing may be done a little later, and to get the best results a good depth of plowing is necessary, and then the plow should be followed with the sub-surface packer. Mark you, we are after a condition that will not only enable us to get the best possible results, but prevent the serious damage by drouth and assure good crops annually, which means prosperity in its highest degree. A fine, firm seed bed, or root bed, has many advantages over the coarse, loose condition.

In the first place one-third of the seed only is necessary. In the next place the growth and development of the plant is much more rapid and will soon cover the surface. In the third place the development of roots is much greater, we are able to draw moisture and plant food from a much larger percentage of the soil, and last, but not least, we have a condition of soil that will hold a much greater per cent of moisture as well as one having a greater power of capillary attraction, enabling us to keep up the supply of moisture which we draw from below, where, by careful work, much of the rain waters are stored, that under ordinary conditions would have been lost by evaporation or run off.

The plan of raising wheat by plowing every third or fourth year and simply using a disk for two or three consecutive years, or even reducing the cost still further of putting in the crop by using a disk drill, is altogether wrong. While it is not at all surprising that many farmers resort to this instead of simply plowing three or four inches deep, leaving the plowing without even harrowing, laying up light and loose, full of cavities, a condition that could scarcely produce anything but weeds in an ordinary dry season. Yet it seems like folly for a man to so prepare his ground that nothing but a very favorable season could give him even a fair crop, with a little additional work, he is able to so materially increase the yield, as well as to guard against a failure. No farmer should be content to call twenty bushels of wheat a good crop. Our prairies of the semi-arid belt are capable of producing forty and fifty bushels, with the conditions nature has provided.

GROWING POTATOES.

Growing of potatoes throughout the semi-arid belt seems generally to be looked upon as too uncertain to even be considered, in spite of the fact that there are many individuals who are raising them and yearly making money. There are instances even in sections of southern Nebraska where they were less favored in 1901 with spring rains than in most any other portion of the state that good crops were grown. In one instance over one hundred bushels of choice potatoes per acre were raised on a twenty acre field and were sold for an average of \$1 per bushel while the general potato crop in that section was a total failure,



Cut No. 14, Magnified roots and soil.

the entire work of the season being done in line with our system of cultivation. The potato is a little different from any other crop and requires close attention during certain periods of its growth. There is no reason why good paying crops of potatoes may not be grown every year at almost any point from Canada line to Oklahoma, barring the ravages of insects or leaf blight, both of which are usually easily controlled by close attention and the use of proper remedies.

PREPARING THE SOIL.

To secure a good crop of potatoes much care and attention must be given to the preparation of the seed and root bed. A glance at cut No. 6 shows the ideal condition. This soil was plowed eight inches deep

after having been thoroughly disked to a depth of fully three and a half inches; the disking having been done early our soil was moist and was in the best possible condition to plow: as the furrow rolled over the fine, dry top soil went under, the moist soil coming to the surface in an ideal condition, and while moist the particles seemed to readily separate one from the other and adjust themselves without material resistance to the desired compactness, as the packer wheels rolled over the plowed ground, which was done quite close to the plow. While we have said much upon the importance of a proper condition of the soil when all work is done, we must almost repeat it again, because so very much depends upon this to secure fineness, firmness and moisture in the soil such as may be most favorable to a rapid and full development of roots such as will lead them to permeate every part or portion of the soil as shown in cut No. 6. In this, however, only the main lateral roots and branches are shown. The little hair roots or feeders may be found in such soil running in every direction, so completely filling the soil as to draw moisture and plant food from every portion. In cut No. 14, we illustrate a condition that should be well understood. It represents at the right a section of a branch root showing the cell formation: from these outer cells are the hair roots or feeders, A A, running through among the particles of soil represented by the dark spots; around these spots are lines parallel with the shape of the particle of soil which represents the film or covering of water. The white spots represent air spaces. Now, if the reader will look at this cut and think for a moment that these hair roots or little tubes marked A A in their full size in the soil are barely perceptible to the naked eye, and then imagine that these soil grains and air spaces here shown are proportionately smaller in their real soil condition, he can catch the ideal condition as shown in cut No. 11.

If you are after a sure crop, as well as a good crop of potatoes, get your root bed as near this condition as possible. Having previously succeeded in storing a liberal amount of moisture in the soil below, as shown in cut No. 8, you can plant your potatoes knowing you have done all you could do to assure success so far.

Planting may be done at the time of plowing by dropping the potatoes on the side of the furrows about three inches from the bottom, letting the next furrow cover them; or complete the preparation the same as for any crop and then plant with a potato planter about four inches deep.

SEED.

As to variety and quantity of seed, we favor the well-bred early Ohio, and prefer large potatoes and cut them as near to two eyes on a piece, putting one piece in a hill. For the more arid portions of the

semi-arid belt we would plant the rows about three feet ten inches apart and drop the seed, cut as above, about twenty inches apart. In the lower altitudes, or where there is a greater rainfall, plant somewhat closer. Remember, the one great point is to never let your potato plant lack for water. If you do your crop suffers. Small and knotty potatoes are the result of the potato plant getting short of water at certain times, which tends to force the ripening or maturing period. Then a sudden and heavy rainfall or the irrigation of the potatoes after this condition forces a new and rapid growth which results in setting a second lot of potatoes, some of which may appear on the roots and others on the sides of the already formed potato.

CULTIVATION.

With your crop in the ground under favorable conditions, then comes the important work. There is no better tool in the early cultivation than the harrow or weeder if you will use it freely and with some judgment. The long toothed weeder may be used from the time the crop is planted until the tops are too large to draw through between the teeth, providing you catch the soil in just the proper condition, especially in the average sand loam soils. Should you get a very heavy rain that may result in packing the surface to a considerable depth, then it will be necessary to cultivate with some fine tooth cultivator, as in cultivating corn, but in such a case it is well to follow the cultivator closely by crossing the rows with the weeder. This more completely fines the mulch as well as levels it, also loosens the soil among the vines and cleans the young weeds. Watch closely the condition, however, and be sure to keep the soil stirred deep enough, even if it is necessary to use the cultivator; a mulch of fine, loose soil of fully two and a half inches in depth should be kept as soon as the potato tops get to any size, and the soil should be stirred often enough to keep the top of the firm soil beneath the mulch in a moist condition. This condition can be kept if you have moisture stored below and do not plant too thick and watch your time of cultivation. Upon the care and attention given over to this part of the work depends the quality and quantity of your crop. Don't stop cultivation when they are in blossom, but don't destroy the roots.

If you want to raise a prize crop put them on a piece of summer tilled ground, plowing again in the spring fully eight inches and handle as suggested.

RAISING TREES.

No question is worthy of more consideration so far as the comfort and happiness of a family is concerned which resides on the farm than that of growing trees. There is nothing more delightful after a noon-day meal in mid-summer than to quite recline in a hammock in the shade of a large elm, but this to the average resident of the semi-arid belt for several years has seemed an utter impossibility. There is nothing more easy, or more simple.

The experience at the Pomeroy Model farm during the past five years quite clearly demonstrates this fact. The piece of land selected for the buildings around which a large number of shade and ornamental trees were set, and for the orchard, is on a high divide overlooking the town with quite a considerable south slope. The south slope is much more unfavorable than the north, as it gets the rays of the sun more directly and catches the force of the south winds during the extreme heated portion of the season; but this south slope was purposely selected that visitors might see that what could be done under such conditions might be done at any point. For the most successful growing of trees or orchard a northeast slope should be selected as most favorable.

The ground for our trees was first double-disked early in March, 1900, plowed in April about eight inches deep, the plow followed by the sub-surface packer, and the packer with the Acme harrow. The ground was then laid out by using the cheek chain of a corn planter. A small stake six inches long was set for each tree or shrub, and nine hundred and sixty-four of these stakes were thus set. When the trees were received from the nursery a deep trench was dug and all trees heeled in with tops pointing north. Care was taken to keep the roots from the air, and what is most important, to keep them moist. When taken from the boxes they were quickly covered with dirt and water turned on. A kerosene barrel was sawed in two parts, each half barrel was filled about two-thirds full of water, and sufficient dirt was added to form a thin solution of mud. Then the trees were taken from the trench when the workmen were ready to engage in the actual work of setting the trees, and put into this solution one by one, and enough mud adhered to the roots to keep them protected from the air and sun while being handled during the process of setting.

Two boards four feet long by six inches wide were provided with a notch in the center and a notch at each end, both boards being cut exactly alike. The man who dug the holes used one of the boards, and placing the center notch on the stake pulled the stake and set it in one of the end notches and added another stake in the other end notch. He then removed the board and dug the hole. In digging the hole the

tree was examined to note the size and shape of root and hole dug sufficiently large to allow spreading all the roots out their full length and no more. The man who directed the tree setting carried the second notched board and after the hole was completed he placed the board on the two stakes, and dropping his tree into the hole brought the body to the middle notch, thus holding it exactly where the original stake had been set.

In setting the tree a helper using a hoe pulverized the dirt that was still fresh and moist, hauling it to the roots as fast as a man could place it with his hands and by the aid of a trowel. Great care was taken to work the soil in about the roots. When sufficient dirt was in to cover the roots a quart of water was turned in. By vibrating the tree slightly the water soon percolated through the moist soil, dissolving the particles and settling them closely around the roots. The holes were then filled within two inches of the top, and then tramped firmly. Then about three inches of loose dirt was scattered over this packed soil and the tree left. This plan was so successful that in the spring of 1901 we were obliged to reset only seventeen trees, less than two per cent, the trees all having made a very fair growth the first year. The expense of caring for these trees in 1900 outside of the trimming, but including all other work and cultivation, amounted to \$22, or about \$2.25 an acre.

The plan of operation was immediately after settling the trees to double-disk the entire surface, because the hauling of the wagons and tramping of the men over the moist soil while setting the trees resulted in packing the ground considerably. A two-horse disk was used for this work, which enabled us to get very close to the tree. As soon as a rain of any magnitude had fallen, the ground was gone over with the Acme pulverizing harrow, crossing the work done with the disk. This harrow is a tool pretty generally known, and a most valuable implement for this class of work. No weeds were allowed to grow. About two and a half inches of the surface was kept constantly loose and fine by the use of the Acme until July, when a second double-disking was applied. The object of this occasional disking was to cut deeper to prevent even the slightest degree of crusting beneath the mulch. Then the Acme was used, going at right angles each time with the previous cultivation until September 1st.

Up to this time we had been inclined to follow the ideas of most orchard and tree men and horticulturists, which was to discontinue cultivation after August, the object being to check the growth of the tree and allow the new wood to mature before freezing time. This idea presumably is correct in the more humid portions of our country. But in the semi-arid section we are inclined to discredit this theory in its full extent. We believe the cultivation should be continued, but less frequent. We must not lose too much of the moisture from around

the main roots and their branches, if we would carry our trees safely through the winter. This question is a nice one and must be treated with care. It is proper to reduce the sap in the body and limbs slightly, but there is danger in going into the winter with soil too dry about the roots. Much attention has been given to this point by most of our agricultural colleges the past four or five years.

From bulletin No. 52, issued by the University of Illinois in 1898, we take the following. We quote it especially because it corresponds to our own experience and is the result of several years of observation:

"Throughout large sections of Illinois may be found the rotting remnants of once extensive orchards, representing large original expenditures of both labor and money. The frequency with which such localities are met would almost seem to justify the statement usually heard in the neighborhood where such worn out orchards are found that the soil is not fitted for the growing of fruit. On the other hand the enormous apple and other fruit production in other parts of the state, and frequently in localities not far distant from those mentioned, makes it evident that the reason so often assigned cannot be the correct one.

"On examination and inquiry it will be found to be almost invariably the case that the true cause for the failure or the dying out of an orchard is the lack of proficient, or the entire absence of proper cultivation and care. While the Illinois agriculturist has been devoting his time and attention to the care of his field and garden crop, it is too often the case that the orchard has been left to care for itself, with the above mentioned result. The commonest cause of failure in orchards in Illinois may be traced direct to the ill effects of summer drouths, though perhaps it is more commonly referred to freezing in winter. The connection really existing between these two destructive agencies has not been often recognized. The fact that certain varieties of apples usually accounted hardy even to our most northern limits, and in exposed situations sometimes fail after a winter not noted for severity, has at different times attracted attention, but the significance of such failures does not seem to have been duly appreciated. On consulting the records it is found that orchard injuries and exceptionally severe winters do not coincide. The autumnal condition of the trees clearly has to do with the results, and this again depends upon the developments of the growing trees. One of the worst things than can happen to trees is the failure of a sufficient supply of soil moisture. A continuous supply of water is essential to all the vital processes of vegetation. Apple trees severely suffer when not so supplied."

The bulletin continues at considerable length along this line, and then presents two very striking cuts, on pages one hundred and twenty-six and one hundred and twenty-seven. One showing the orchard upon the college farm, with trees hanging full of fruit, the other of an adjoining

farm with neglected trees uncultivated, bare of fruit and almost minus of foliage, and the bulletin concludes by referring to the cuts in the following manner:



Cut No. 15. Peach tree five months after setting.

"The photographs were taken in September, 1897. The tree in the foreground of the college orchard, with its wealth of foliage and bending under the weight of its load of fruit, tells its own story, and stands forth in marked contrast to the preceding picture, which is bare of fruit and almost minus of foliage. From the contrast there can be but one con-

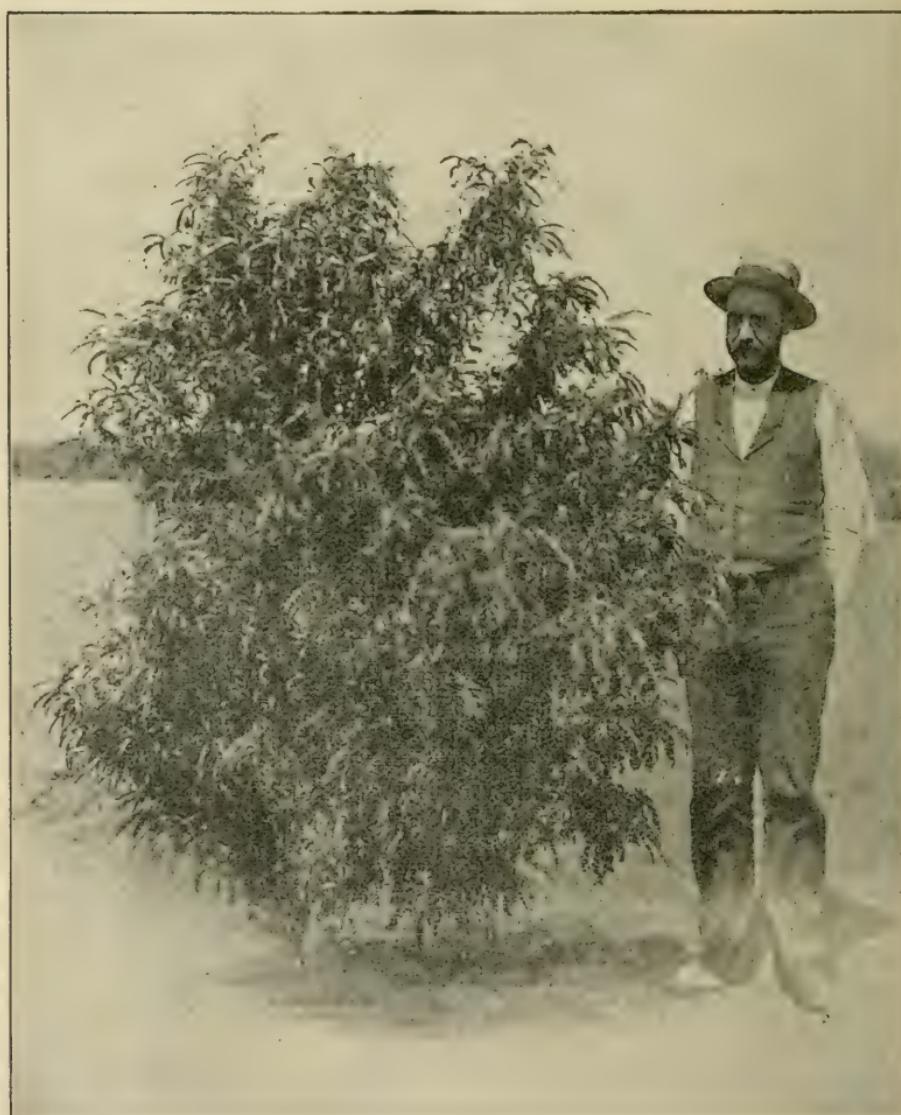
clusion drawn, that while other things have greater or less effect upon an orchard's health and condition, the prime requisite to successful orcharding in Illinois is thorough and systematic cultivation."

While the principles involved in the Illinois bulletin are important and valuable in that state, they are vital with us in the semi-arid section. The prevailing idea, and the idea usually drawn from most of our articles, is that the work is too expensive to make orchard growing profitable in the more arid portions of this country. This is quite an error, fully demonstrated by the figures given of our own work in the orchard of the Pomeroy Model farm in 1900.

In cut No. 15 may be seen a peach tree grown in the Pomeroy Model farm orchard, from a photograph taken in the fall after the first year's growth. These trees were all cut back to about three feet when they were set, and all limbs cut back so as to leave about two buds on each. Cut No. 16 illustrates one of the same trees August 23, 1901, on its second year's growth. The contrast is so remarkable that it may be taken as sufficient proof that trees may be grown in the more arid portions of Kansas, Nebraska and eastern Colorado, without irrigation, and what is true there is equally true in other portions of the semi-arid belt.

The body of the tree shown in cut No. 12, at the close of the first year's growth, measured a little over one inch in diameter, while the body of this tree as shown in cut No. 17 at the close of the second year's growth measured two and a half inches. As the man standing by the tree measured six feet, three inches, to the top of his hat, the reader may get some idea of the remarkable growth of these trees. There is no reason why they should not have made this remarkable growth, for, although we experienced a continuous dry period with the excessive heat of one hundred degrees and above for forty-three days, from June 18 to August 1, entirely without rain; yet during that entire time the ground was amply moist to make into balls about the roots of the trees, and to a depth of over ten feet. During this entire time, owing to the manner of cultivation and the care taken to save the moisture, this soil was practically as full of moisture about the roots of the trees as it could hold, and had there been previous irrigation from a ditch the soil could not have been more moist.

In cut No. 17, is shown a white elm tree. Looking closely you can see the man's hand about four feet from the ground, grasping the pole which is ten feet high. At this point where the hand shows, the tree was cut off when set in the spring of 1900. The growth during 1900 was not much, though quite as much as might be expected the first year, the new limbs averaging about ten inches. This photograph was taken August 23, 1901, when the tree reached within eight inches of the top of the ten-foot pole. Elms are usually considered slow growth. This illustration is certainly a demonstration of two facts, that they will



Cut No. 16, Peach tree seventeen months after setting,
Pomeroy Model Farm.

make remarkable growth with plenty of moisture, and that moisture can be stored in sufficient quantities on the far western prairies to supply all necessary needs of such trees.

In the setting of trees or orchards in the more arid portions of this belt, care should be taken not to get them too close together. A suc-



Cut No. 17, White elm seventeen months after setting.

cessful growing of a tree depends upon ample pasturage of the root. In our orchard at the Model farm we set our cherries and peach trees twenty-two feet each way, and our apples twenty-two by thirty-two feet. No crop of any kind or nature should be grown in an orchard if you would secure the best results. It may seem like a waste of ground

to see little two-year old trees standing two and a half to three feet high, with tops only one foot to eighteen inches broad, twenty-two feet apart each way; but when we note the immense growth of our trees the second year we see it is not long before the entire space is utilized. Back of the house where we lived in Holdrege, Nebraska, is a cherry tree that now measures seventeen and a half feet across from tip to tip of limbs. You can readily see that in the twenty-two-foot distances we only have four and a half feet left. Now if you expect the trees to make this growth you must not interfere with the roots of the tree; or in any way rob it of any of the moisture or plant food in the soil. Besides, to plant a crop of any kind would make the cultivation much more inconvenient and expensive. A trip back to the old eastern states, even in Illinois, and then on through Ohio and New York state, will disclose a radical change in methods of handling orchards. The most profitable orchards in those states, today, have no crops or grasses growing in them; while twenty years ago it was a common practice to seed them down to grasses. If that kind of treatment is desirable and profitable in the east where the rainfall is more than abundant, it is much more desirable in the West.

We can now cite many instances of successful tree and orchard growing in western Kansas and Nebraska and eastern Colorado, but space will not permit. For further evidence of the importance of frequent cultivation of trees read Chapter X, and for more emphatic evidence of the marvelous growth that can be attained by proper cultivation of both fruit and forest trees, visit the Pomeroy Model farm in mid-summer and behold the lofty and beautiful shade trees of only five summers' growth. Nothing succeeds like success.

SUGAR BEETS.

Cultivation of the sugar beet is worthy of considerable attention among farmers, outside of the question of growing them for the sugar factory. With the careful preparation of the soil, which should differ in only one respect from that which we have outlined for other crops, and that is deeper plowing, but the same care taken in thorough pulverizing, and in the more arid portion thorough packing, large yields may be secured. Cut No. 18 shows a field of sugar beets grown at Lisbon, North Dakota, on the grounds of the Soldiers' home, under the direction of Colonel McIlvaine, in 1897, the second year's experiment on the same ground, under the so-called Campbell method of soil culture. The phenomenal yield of forty-six thousand pounds per acre was secured, or twenty-three tons. It may be readily seen from this illustration the

vast amount of valuable feed that can be raised from a very small piece of ground. The question of the manufacture of beet sugar has received no little attention in this country during the past ten years, and considering the wonderful results that have been obtained by feeding beet pulp after all the sugar has been extracted, is a strong argument in favor of the growing of these beets by all farmers. To one who has not raised beets or other garden vegetables, except in little plats for domestic



Cut No. 18. Sugar beets, 23 tons per acre, by Campbell method.

use only, it may seem like a very tedious job and quite expensive. But this is not true. With a fine toothed cultivator and by drilling the beets in rows two and half feet apart, almost the entire work can be done with the horse, requiring a little hand work in thinning. Here, too, some surprising results can be attained. In the extreme northwest portion of Kansas, only twenty-eight miles from the Colorado line, in 1898, we raised as fine beets, parsnips, turnips, carrots, and onions, on the high level prairie, as any man ever saw, with very little work, except what was done with the horse and cultivator. The average farmer in

that section did not believe it was possible to raise garden vegetables, and little attempt to raise them had been made for some time.

Sugar beets have been fed to sheep, cattle, and hogs in experiment at many of our agricultural colleges, with other feed, always with good results, especially in feeding sheep.

ALFALFA.

Alfalfa, like all other crops, thrives best under the most favorable conditions. There is probably no point in the raising of alfalfa more important than that of securing a good stand. It seems almost impossible, in fact, climatic conditions must be very favorable, in order to get a catch of seed in reseeding spots among well rooted plants. There is no seed that responds, or returns greater rewards for a good seed bed than alfalfa, and yet it is a very simple proposition, and if the proper course is pursued and good seed used there is practically no question about securing a good stand. On the high divides in many localities in Nebraska and Kansas, alfalfa is being raised quite satisfactorily, the only difficulty generally being an uneven stand. The summer culture plan by which one season's rain is stored in the ground, and the soil carefully prepared as outlined in the chapter under this heading, then sowing the seed the following spring, taking care to loosen the surface soil the first opening of spring is best. The best results I have ever seen in western Kansas have come from seeding early in April on ground thus prepared, with ten pounds of seed put in with a shoe drill with a chain cover.

The next best plan is thorough culture from early spring to July, together with careful preparation, then seed in July with ten pounds of seed with drill or twenty pounds if broadcast. At the time of seeding the above field there were about two inches of loose, fine soil on the surface made by the use of a common harrow, and the shoe set so as to put the seed from one-half to one inch into the solid, fine, moist soil beneath. The seed came up quickly and very even, and if there was any complaint to be made it was the fact that it was too thick. With the prevailing price of alfalfa seed the saving of a few pounds of seed is a great item, especially in putting in large fields. The further fact that when once sowed and the crop established it is there for years to come, certainly is sufficient argument to support the demand for thorough and careful preparation of the seed bed.

The summer culture idea involving this storage of one year's rainfall puts the soil in such condition for five or six feet down that the tap root

immediately pushes on down through this moist soil sending out the little feeders on their way down, and the chances are that a good crop may be harvested the first year, as was true in the case above referred to, due only to the fact that the soil conditions were perfect for the rapid development of roots, and ample moisture to produce this magnificient growth. While it is true that much better results are attained from alfalfa in valleys where sheet water is eight to twelve feet from the surface, yet a sufficient number of experiments have been made and in some of them a sufficient length of time has elapsed, to warrant the statement that on the majority of our high divides in the semi-arid belt as good or better yields can be secured from this crop than are commonly harvested in the eastern states on the average meadows of timothy and clover. The value of lands where the phenomenal crops or yields of alfalfa along some of the valleys in western Nebraska and Kansas has hardly come to be understood, or fully appreciated even by the people who have raised them. We are familiar with fields that for three successive years have turned off in alfalfa hay alone from \$30 to \$40 per acre, and where hay and a crop of seed has been harvested as high as \$80 per acre has been made. The value of this plant for feeding hogs, cattle, and sheep is just beginning to be appreciated. All experiments thus far carefully conducted have demonstrated that there is no fodder plant so valuable.

The preparing of fields for seeding to alfalfa on old ground cannot be better explained than the instructions under the heading of Summer Culture for spring wheat. But if the reader must sow without giving the year's cultivation and storage of water, then keep in mind two fundamental principles, viz: plenty of stored moisture in the soil below and a fine, firm seed bed. Theré is economy in these, as you can not only get a better and more even stand with much less seed, but your chances are increased many fold for getting a good stand regardless of what the season may be.

SEEDING ON NEW BREAKING.

Alfalfa, like many other crops, may be sowed on new breaking the same season the breaking is done and sometimes get satisfactory results, but considering its uncertainty and the difference in the value of a good crop as against a poor crop and possibly none at all, we are inclined to give over the whole season to preparing for a good crop is then practically assured.

Breaking should be done when the grass is growing the fastest, for at this time the sod seems to more readily and more completely rot. Let the plow run about two and one-half inches deep, using every possible means and care to lay the furrow slice flat and roll down solid either with the packer or a disk set straight, then harrow; here again the Acme

harrow comes in with good results, the object being to loosen enough dirt from the sod to fill all the crevices between the furrows and form a perfect blanket to hold all the rainfall down under the sod, then take care of the big rains by harrowing again. If this is fully accomplished the sod will not only be fully rotted in a very short time but the top of the subsoil beneath will also become rotted to a depth of two to three inches. As soon as this is found to be true, then begin backsetting or plowing with the stubble plow, cutting about two and one-half inches deeper; follow the plow with the packer as explained under the heading of Plowing and Sub-Pack ing, then follow with the harrow, the Aeme preferred, getting it all fine and firm before it has time to dry out. Look well to the storage of later rains and be ready to loosen the surface in early spring with the harrow and put in your seed fairly early, governed largely by the locality, using not over ten pounds of good seed with a shoe drill and chain cover. If your work is all well done, as outlined, you need have no fears of the result.

CROP ROTATION.

We are not advocates of crop rotation any farther than it can be carried out as a matter of convenience or the advantages that may be gained in putting in crops. In this regard there is an advantage in rotation by a three-year plan in the semi-arid belt.

FIRST YEAR.

Begin by summer tilling one season. Go at it with a will and see to it that you store and conserve the entire season's rainfall from early spring to autumn. Keep out the weeds. Sow your fall wheat, if in central or southern Nebraska, first to tenth of September; if in northern to central Kansas, sow from the tenth to the twentieth of September, using not over thirty pounds of seed. If your work has been well done and the soil in good physical condition, do not sow more than twenty-four pounds of seed per acre! Remember that our dates for seeding and quantity of seed are based on thorough preparing, under which conditions it will be found that the fall growth will be ideal.

SECOND YEAR.

The second year we harvest our wheat crop in Kansas in June, in Nebraska the last of June or early July. From the harvesting of this crop to the close of the season we prepare for the crop to be grown the third year as follows:

If possible, follow the harvester with the disk. If you cannot do this go over the field with the disk just as soon as the crop is cut. Whatever you do, double-disk as elsewhere explained. The quicker and more thorough you do this the better will be your crop the following year. After double-disking continue just the same as if summer tilling. Keep the weeds down at all hazards and get over the ground with some tool as quickly as conditions will permit after each rain. Plow as soon as the soil is in condition, following all work after plowing the same as for summer culture and you are ready for a crop of corn the following spring, or oats if you prefer, but corn is preferable and if well tended you can bank on a crop.

Very much depends on the work being done immediately after the crop is cut for two very important reasons. First: Evaporation is very rapid after the crop is removed and must be checked in order that the plowing may be done early. Second: The hot sun of July and August is very valuable if you can hold a per cent of moisture just beneath the mulch. It promotes nitrification which sets free much plant food and care should be taken to prevent any weeds growing to utilize the nitrates or steal your moisture and plant foods, which you can and should hold for the following crop.

TWO CROPS IN THREE YEARS.

This plan if faithfully and carefully carried out in sections similar to western Kansas and Nebraska will result in two good crops out of three years of a proportionate magnitude to the crops reported elsewhere by the every other year plan by summer culture one year and cropping the next. In a series of ten years will produce average crops that will compare favorably with the average crops grown in Iowa or Illinois under the present general methods in the same number of years.

ARBORICULTURE.

ITS VALUE AND IMPORTANCE.

The following article written by the late J. Sterling Morton expressly for our 1902 Manual, but a few months before his demise, coming as it does from a man of such broad ideas and wide experience, having been four years Secretary of Agriculture at Washington and for more than forty years a resident of Nebraska, as well as being recognized as the father of Arbor Day we feel the words are worthy of space in this volume, if nothing more than for his great interest in and friendship for the work we have so long been promoting.

Mr. H. W. Campbell:

DEAR SIR—After an experience of more than forty years at Arbor Lodge, adjoining Nebraska City, in the County of Otoe, I declare that the best method of planting forest trees is in rows running north and south. The first row on the east should be of a rapidly growing variety, like catalpa, speciosa, cottonwood, aspen, or soft maple. The next row should be a nut-bearing tree, like the black walnut, butternut, or coffee bean. The next succeeding row on the west should be, like the first one of a rapidly growing variety. Planted in this way, the swiftly growing trees act as nurses for the slowly growing trees. Planted, thus, black walnut, instead of putting on a scrubby growth and looking like gigantic quince trees when they have reached twenty years of age, run up towards the sun for light and make good trunks of twenty feet in length. This wood is valuable, and trees thus planted are grown with relative celerity. At Arbor Lodge I have between 100 and 200 walnuts thus treated, which were put into the ground in the autumn of 1865, and if you could see and measure them, it would be a work of supererogation for me to make further argument in favor of this system of planting. To grow either deciduous trees or any variety of conifers on these plains with any degree of success, it is necessary to plant them close together. All great forests, whence have come the best timber that man has ever used for building and cabinet woods, have been dense. The vast pineries of the Northwest were so closely planted by nature that it was impossible for a horseman to ride through many of them because of the interweaving branches. To successfully grow trees like those the forests produced, we must endeavor to create forestal conditions.

In 1892 I planted out 10,000 white pines, purchased of Robert Douglas' Sons at Waukegan, Ill. They were two years old and averaged perhaps a foot to 14 inches in height. They were planted in rows 4 feet apart, and the trees were 4 feet from each other in the rows. They were cultivated three or four years with the plow, the same as corn is cultivated, the furrows going first east and west and then north and south. They have made a remarkably fine growth, both as to height and circumference. Many of them are from four to five inches in diameter and from 18 to 20 feet in height. It is with difficulty that a man can walk among them, and last summer when the drouth and hot winds were doing their worst to smother and parch out vegetation in this section of the country, those pines showed no indication of distress. Going in among them and stooping down, and looking under their lower limbs, one could not see a single particle of vegetable growth aside from the trees. The ground was thoroughly mulched with the needles which had fallen from them, and blanketed the earth, so to speak, with the mold which they had created. Removing this carpet of needles one could find moist, cool soil at all times. The conditions about the roots of these

trees were such as their ancestors found in the great pineries of Wisconsin, Minnesota and Michigan. Many varieties of trees have been condemned as unfit for cultivation in Nebraska, after trying them in isolated positions, exposed to the hot sun and drying winds from the southwest. Trees are almost as gregarious as human beings. No man or woman could have been perfectly developed, physically and intellectually, in absolute solitude and without communication or intercourse with other human beings. And just so, no single tree planted out on the hot prairie, exposed to the burning sun all day long, can make as perfect a specimen of its kind as can be grown where trees are clustered together.

Arboriculture is absolutely indispensable to the conservation of other plant life, and even to the existence of animal life on these plains. The interdependence of the lives of trees and the lives of human beings is constant. If a single summer should be passed without foliage, flower or fruit on the globe, all animal existence would cease.

Your great work in soil culture is thoroughly appreciated by every thinking citizen of Nebraska. Your intelligent efforts to benefit the agriculture and horticulture of this state are of greater value to your race and to those who come after you than all the efforts of all the members of congress who have ever represented this commonwealth at Washington. It is a gratification to realize that soil culture and arboriculture are destined, without asking an appropriation from the general government, to revolutionize the climatic and productive conditions of the state of Nebraska. Just as plants need light and as potato sprouts in dark cellars seek the windows and doors where the sun's rays occasionally stream in, so all the people of the prairie states need the illuminating practicalities of your researches and experiments in soil culture, which illustrate the method of insuring crops by intelligent tillage against destruction by drouths.

ADBOR LODGE, Jan. 18th, 1902.

J. STERLING MORTON.

IRRIGATION.

It would hardly be proper to close our book without a word on irrigation, especially considering the fact that some have seemed to conceive the idea that our system was antagonistic to irrigation and that the promotion of this work generally would retard the development of irrigation enterprises, but this is far from the truth.

We have millions of acres of the most fertile lands, level and easy of cultivation, that can never be irrigated without unwarranted expense, which receive ample rainfall annually to produce fine and profitable crops, if these waters are properly stored and utilized. Then there are millions more

of choice lands with sufficient rainfall to make irrigation impracticable where the present average yield is not to exceed one-third what it might be if the general principles outlined in our book were fully understood and practiced.

Then again we have millions of acres for which irrigation is necessary to secure profitable returns but the available water is not near equal to the acres, when the waters are so wastefully used as is the case today along most of our ditches.

The fundamental principle upon which the success of our system is based, is the economical use of water, it matters not from whence it cometh, whether direct from the clouds or from the flowing streams, ditches, reservoirs, or wells. The first and very important thing to do is to get a supply of water stored in the soil to feed, nourish, and mature the crop in a period of dry weather, and the second and almost equally important requisite is the seed and root bed, so vital in the success of our system, all of which is necessary in growing crops by artificial application of water required by irrigation.

We do not mean to be understood that a man may not get a better crop with plenty of water to turn loose at will upon a piece of ground poorly fitted than he could with the same reckless fitting and be obliged to depend upon replenishing his soil with moisture from the heavens, but this is not the question today with the progressive farmer.

It is how can we get the greatest results from our soil, labor and expense considered? In irrigation, water usually means money. There are few irrigation ditches today that carry enough water through the season to irrigate all the land that might be reached with water from the ditch. There are many fields that are made to suffer that are under the ditch and crops made light that if the principles involved in this book were understood and applied precisely as we outlined them to these fields, larger yields might be realized, and more acres covered with the same amount of water when the irrigator better understands the nature of plants and just what physical condition is best for the support of healthy roots and how they gather plant foods. Due consideration must be given to the roots of the plant and their necessary supply in proper quantities, not only of water, but of air also. Too much water at times is just as detrimental as too little water. A clear conception of how water moves in the soil is just as important to the irrigator as to the man who depends solely upon the rainfall.

The ideal condition for the most healthful and successful growth of all cultivated crops is a good depth of root bed made thoroughly fine and firm. There is little danger in getting the average sand loam soils, so common in the arid and semi-arid sections, too firm, while some of our heavy clay soils if not properly handled might become too closely compacted, but this kind of soil is not at all common. Previous to the

thorough fitting of the seed and root bed see to it that ample moisture is stored below where nature can do her part by bringing it up to the roots of the growing plants by capillary attraction, then keep your surface always cultivated in such a manner as to provide as near as possible a fine, loose mulch of soil (not dust), stirring it often enough to keep the moisture up to the top of the firm soil just beneath the mulch. The moment the top of this firm soil becomes in the least dry there is immediately a process of depositing of salts and other matter between these particles of soil closing the pores and consequently diminishing the quantity of air that should freely pass through this soil to the roots. This condition not only points to the fact that you are allowing the air to be shut out but that you are losing moisture by evaporation from the soil which may be checked by cultivation. In fact, there should be no dry soil above your moisture except what is loose and fine. See to this point at all times. Note our explanation on this subject under Growing Trees.

Our article on percolation should be of interest to the irrigator as it indicates under what condition he can most economically apply his water.

The articles on Evaporation and Capillary Attraction should likewise be studied. Sub-irrigation is being practiced with marvelous results in some instances. This demonstrates clearly that if the irrigator will watch his opportunity and will turn on his surplus water in the fall after his crop has been removed or during the winter or early spring, with the water stored in the soil below and care in conserving the moisture by proper cultivation, fine crops can be grown with very little after irrigation.

WINTER WHEAT BY IRRIGATION.

Very large crops of winter wheat should be grown on the average soils in Colorado and sections under similar conditions if special effort was carefully put forth to irrigate thoroughly, immediately after the crop is harvested, then double disk as soon as the surface is sufficiently dry to do the work without sticking. Plowing later using great care to pack the plowed portions and harrow the surface while moist, seeding sufficiently early for a good fall growth, then harrow early in the spring, then with one irrigation after the foliage fully covers the surface, sixty bushels per acre should be common under such conditions. In all crop-growing under irrigation, much consideration should be given to the chapters under the following headings. Physical condition of the soil, air and its importance in the soil and the water holding capacity of the soil.

NECESSARY FARM TOOLS.

Since publishing our first manual in 1901, we have been asked many times for a list of the implements we consider best adapted to general farming on the prairie of the great semi-arid belt. This, we realize,

is a delicate subject on which to give advice, therefore, we simply give a list of such tools as we bought for the Pomeroy Model farm at Hill City, the Burlington Model farm at Holdrege and will buy for other farms we are opening up this spring.

For ordinary sized farms we favor four horse tools, or larger, as far as it is possible. To decrease the cost of production adds profits, the same as to increase the yield. When one man can turn over two fourteen-inch furrows or twenty-eight inches by driving four horses instead of sixteen inches by driving three horses, you are not only decreasing the cost of plowing over thirty per cent, but are getting a field plowed in six days that would take ten days with the sixteen inch plow. This is an advantage in many ways and what is true of plowing is proportionately true of all other farm work.

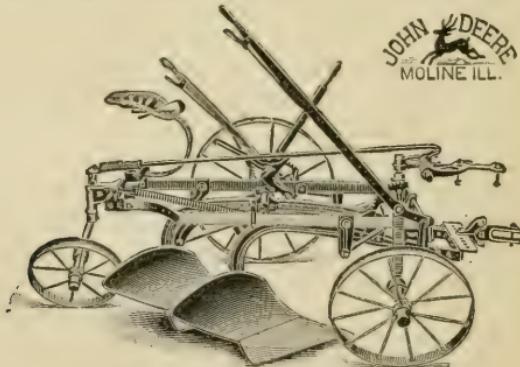
The following tools make a very complete outfit for four good heavy work horses, and with these horses and tools eighty to one hundred acres can be handled by our plan on the high level prairies of the more arid portions of the semi-arid belt where the soils are of the usual sand-loam formation.

LIST OF TOOLS.

- One gang plow, two fourteen-inch.
- One four-horse disk harrow.
- One four-horse Acme harrow.
- One four-horse combination weeder.
- One four-horse Campbell sub-packer.
- One two-row cultivator.
- One one-horse cultivator.

In addition to these tools comes such planters, drills and harvesters as shall be needed for the crops the farmer may wish to raise.

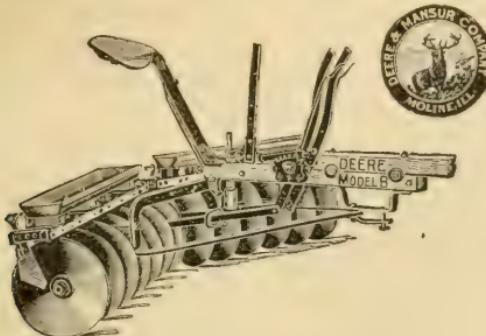
The list of tools is such as has been found most desirable for securing the best possible physical condition of the soil at the least expense.



Cut No. 19, The Gang Plow.

THE GANG PLOW.

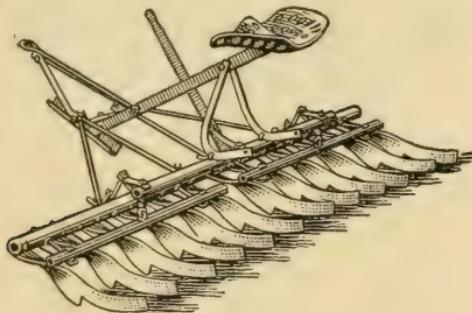
Gang plows are made by most all of the manufacturers and each has its special advantage and may be secured in almost every town or city.



Cut No. 20, The Disc Harrow.

THE DISK HARROW.

Disk harrows are also made in many different styles and patterns and are on sale at all implement dealers. We have a preference for a disk not over sixteen inches in diameter and prefer a fourteen-inch because they pulverize the soil much finer.



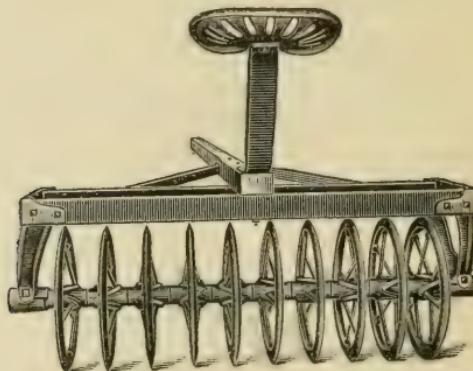
Cut No. 21, The Acme Harrow.

THE ACME HARROW.

The Acme harrow has been manufactured for over thirty years by Duane H. Nash, of Millington, New Jersey, and is not so generally handled but is more easily obtained in the West than a few years ago. We have used many different devices for surface cultivation but have never had a tool we considered so valuable as the Acme. In summer tilling or orchard work it is especially desirable, as once over it more fully fines and levels the surface than two or three times with any other tool. They may also be had of some of the western jobbers.

COMBINATION WEEDEER.

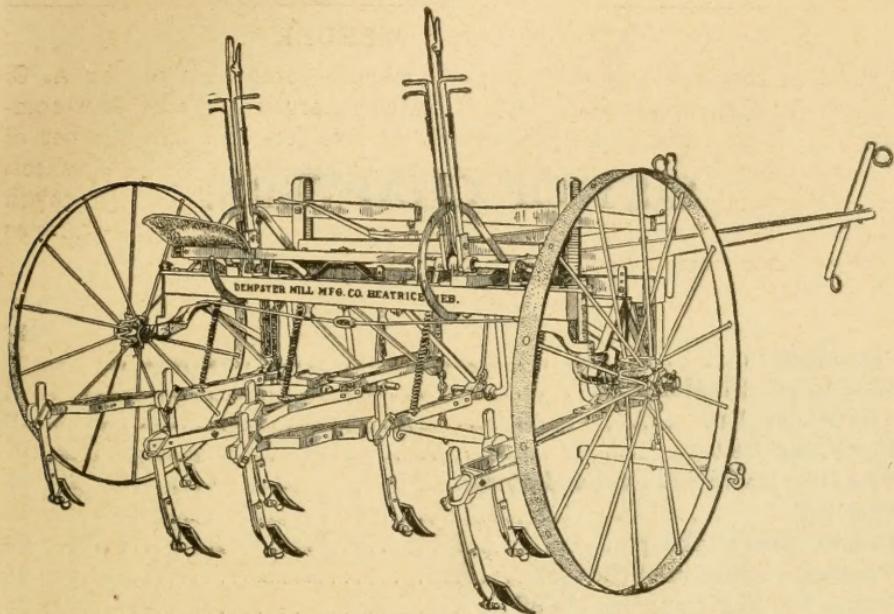
This tool is a new one and now manufactured and sold by A. C. Reeve, of Denver, Colorado. It is really a harrow and a weeder combined. It is made in sections of four to five feet and any number of sections may be attached to the drawbar to cover ten to twenty-five feet. It is especially adapted to harrowing small grain in its early growth and the harrowing of corn since it will not destroy the young plant as the common harrow does.



Cut No. 22, Campbell Subsurface Packer.

CAMPBELL SUB-SURFACE PACKER.

This is a tool that has been manufactured in its different stages of development for some years and recently materially improved. It is the only device on the market that will pack firmly and completely the bottom of deep plowing so that you can get the best results in your crops, and yet leave the surface loose as it must be left if you would raise successful crops in the semi-arid belt. It is manufactured by the Ottawa Foundry and Machine Company, of Ottawa, Illinois, but is now being handled by most implement men.



Cut No. 23, Two-row Cultivator.

TWO-ROW CULTIVATOR.

Two-row corn or potato cultivators are now being made by several different manufacturers and are a great improvement over the one-row for two reasons: They decrease the cost of caring for the crop and enable you to get over your field in half the time, a very important point in conserving the moisture.

ONE HORSE CULTIVATOR.

A one-horse cultivator is quite an important tool in order that you may be able to go over your corn after it gets too high to cultivate with the riding cultivator in case you get a heavy rain that packs the surface. The use of such a tool at such a time has been known to increase the yield of a field of corn more than thirty bushels per acre over adjoining fields.

TOOLS OF VITAL IMPORTANCE.

Of all the tools in the list none is so vital to successful farming by our method as the sub-surface packer. In the more humid sections, East, it is valuable, yet may be dispensed with and run less risk of loss of crops, but in the more arid sections of the semi-arid belt it is indispensable. Do not get a surface packer and expect the same results as with the sub-surface packer.

JAN 28 1905

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COMPLIMENTARY.

With my compliments heartily extended to the receiver of this little Manual, I gladly endorse Prof. Campbell's system of soil culture.

On my model farm, near Hill City, Graham county, Kansas, the efficiency of his methods, as set forth herein, has been fully established and I earnestly advise all farmers in the semi-arid districts to follow his plan strictly and fully.

Trusting that this may be received with the same kindly feeling and earnest desire to promote the general interests of agriculture with which it is given, I am,

Yours very truly,

J. P. POMEROY.